

THE THIRSTY EARTH

“ A river went out of Eden to water the garden.”

GENESIS II. 10.



Australian Commonwealth

IRRIGATING GRAPE VINES, AUSTRALIA

The picture shows the field ditches or irrigation furrows.

THE THIRSTY EARTH

A Study in Irrigation

BY

E. H. CARRIER

M.A., M.Sc., F.R.Hist.S.



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PREFACE

IN writing this book, which makes no pretence of being a technical treatise on the engineering side of the subject, my constant aim has been to present to the general reader, and in particular to the student of Geography and History, a simple yet adequate account of the more important aspects of irrigation in different parts of the world. Naturally, alongside the plain statement of fact, some controversial matter has had to be introduced. On such topics I have usually taken what seemed to be the 'majority opinion,' fully realising that the point of view expressed may not meet with agreement in every quarter.

The importance of such a book has seemed to me to lie in the presentation of the actual geographical conditions rendering Man's efforts at irrigation both appropriate and necessary, the world-distribution of these conditions, the various methods by which irrigated agriculture is carried out, and some of the results arising from such operations.

I have endeavoured to make each section so far as possible complete in itself, and this has inevitably resulted in a certain amount of repetition. Thus, for example, the process known as 'Irrigation by Gravity' is explained in the chapter dealing with Europe, and again in that on the United States. Similarly the description of certain climatic phenomena occurs more than once, but in each case care has been taken to make these repetitions as brief as possible.

Grateful acknowledgment must be made to the Irrigation Departments of the Canadian Pacific Railway, the Union of South Africa, the Commonwealth of Australia, the Reclamation and Census Bureaux of the United States of America, and to the Director of the South Kensington Museum for permission to use maps, pictures, and statistics.

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E. H. C.

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PART I
GENERAL CONSIDERATIONS

THE THIRSTY EARTH

CHAPTER I

THE DESERT AND THE GARDEN

THE study of the earth as the home of man has come to be recognised as one of the most important branches of human knowledge. In the following pages this study will be carried into paths which as yet have not received all the attention they deserve. This neglect may owe something to the belief, formerly very prevalent, that nature was ultimately responsible for the 'furnishing' of man's home, he being merely a 'creature of his environment.' The qualities of the various environments that produced the main broad types of human life were stated with concise emphasis in the earlier textbooks. Among them climate ranked prominently, and the climate of our planet was regarded as divisible into five well-defined zones. Such lines of latitude as the Arctic and Antarctic Circles, the Tropics of Cancer and Capricorn, marked the passage from one to another. Names were chosen to describe their characteristics: Frigid Zones round the Poles, a Torrid Zone bisected by the Equator, with Temperate Zones intermediate in climate and position, the northern one further distinguished as the theatre upon whose stage the main events of the world's long history have been enacted.

Now the parallels of latitude are themselves determined by astronomical considerations, and thus it follows that a classification of climate based on latitude is likewise

dependent on astronomy. The simplicity of the mathematical principles involved must have gone far to recommend it ; nevertheless this method of classifying climates is to-day of theoretical rather than of practical utility.

For it is now known that the Arctic lands may blossom with delicate and many coloured flowers ; that the luxuriance of the tropics may be marred by mosquito-infected swamps which make human habitation impossible ; that the belt of the north Temperate Zone itself also contains no mean portion of the world's desert areas. The hearts of the continents, wherever they may be, are sometimes 'temperate' only because the frigidity of their winters and the torridity of their summers together give bases for that hypothetical mean by which alone they can be regarded as temperate. In this latter respect indeed, taking into due account the distribution of the continents and oceans, we are coming to see that so far from being mainly a function of latitude, climate is no less dependent upon longitude.

But not only may frigid and torrid conditions be found in temperate latitudes : frigid and temperate conditions occur equally in the tropics where the land is of sufficient elevation, and instances may be cited in those 'tierras' of Mexico known respectively as the *Tierra Caliente*, *Tierra Templada*, and the *Tierra Fria* (or hot, temperate, and cool lands), forming stairs or terraces leading upwards from the sea-level to the summit of the great plateau, while the town of Quito in South America, situated almost upon the equator, on account of its combined elevation and latitudinal position enjoys a perpetual spring.

In the Frigid Zone, even in summer, the subsoil is permanently frozen, so that tree growth is impossible : while the lowness of the summer temperature, in spite of the great amount of daylight, prevents the maturing of plants which man might use as food. The vast rains of the Torrid Zone may satiate rather than merely satisfy the soil, though when winter rains are absent the natural vegetation is of the hot

grassland or savannah type. Our present concern is with neither of these regions, but with those thirsty lands occupying the warmer parts of the temperate zones, whether 'temperate' by latitude, *longitude*, or elevation; where summer drought coincides with summer heat, and the annual rainfall may come either at the wrong season to benefit plant growth, or be insufficient in quantity, or be entirely absent.

In these 'warm' temperate regions two tracts of country demand attention, no less by their coincidence in latitudinal position than by their great difference of agricultural yield. They both receive the North-east Trade Winds; winds which, in the first place, have already travelled across extensive land areas, and are therefore dry compared with other winds: and which, in the second place, through moving from colder to warmer latitudes, are ready to gather in more moisture, rather than to give up that which they may possess.

The first of these regions, the great tract of Northern Africa known as the Sahara, is in the main a dreary waste of sand, or bare, weather-scarred rocks and cliffs. The lack of rain results in cloudless skies, from which in the daytime the sun pours down his merciless rays, and towards which at night the heat so bestowed swiftly returns. The cumulative effect of these long continued processes has been a gradual breaking up of such rocks—perhaps mountains—as there were, through the alternate action of an intense daytime heat and an equally intense night-time cold. The Trade Winds which blow over these latitudes, assisted by the storms resulting from the unequal atmospheric temperatures generated by excessive local heating of particular areas, also play their part in the general destruction, sweeping up great clouds of sand or dust, which beat upon and abrade still further the hard rock-face.

Such is the Desert, a place devoid of vegetation except in specially favoured districts traversed by rivers rising in

lofty and distant mountains and thereby deriving water sufficient for certain limited kinds of growth. Occasionally the rivers in question are underground, and from them water may rise to or near the surface, owing to the capillarity of the porous soil. This circumstance produces the oases, which exist as islands of fertility in a sea of desert. Egypt—in so far as it is represented by the riverine lands of the Nile—may be regarded as a great oasis, since its rainfall is negligible and the source of its waters lies in remote, equatorial lands, or in the monsoon outpourings of distant Abyssinia. Unlike many 'rivers' of the Saharan Basin, the Nile flows above ground.

The oasis of Egypt forms a stepping stone between the two regions to which previous reference was made—that Garden of Allah, the Desert, a 'dry and thirsty land where no water is,' epitome of sterility, and that Garden of Jehovah, 'Eden,' epitome of fertility. Here, too, the source of productiveness is revealed in the simple phrase, 'and a river went out . . . to water the garden.'

If Eden were not in truth located in the fork of the Euphrates-Tigris River system, a point still under discussion, it does at least seem certain that early civilizations took their rise somewhere on the alluvial flats at the head of the Persian Gulf. Here the mighty Euphrates-Tigris rolled down never-failing supplies of fertile river mud, drawn from the far-away mountains of Armenia, depositing them in a region which was otherwise barren steppe. The Empire that in time grew up in this territory was based on agriculture, the two rivers in that climate of low rainfall supplying practically the whole of the irrigating flood.

Of man's early dependence upon water, of his terror of a waterless area, the story of the Wanderings of the Children of Israel gives ample proof. The three waterless days in the wilderness of Shur occurred very shortly after the triumphant Exodus, but their confidence in their miracle-working leader was not proof against this supreme terror of

the Desert, and when at Marah their new hope was ruthlessly destroyed by the bitterness of the waters, they began the first of the long series of base 'murmurings.' The life-giving qualities of water, both for themselves or as a means of raising the food for which their souls craved, were always uppermost in their dreary thoughts: "We remember the *fish* which we did eat in Egypt freely," the juiciness of 'the cucumbers, and the melons, . . . and the garlick,' is the burden of their complaints. "But now our soul is *dried* away." "It is no place . . . of figs, or of vines, or of pomegranates; neither is there any water to drink": and so on.

Nevertheless the Children of Israel did at last win through, and, conscious of their great achievement, their entry into Canaan was deservedly triumphant. We of to-day, realizing more scientifically, if not more practically, the wonder-working properties of water in a rainless area, may come to regard the great deserts less as regions of dead or infertile wastes than as lands of much, if of latent, promise, and but awaiting the vitalizing power of water to waken into life and richness.

CHAPTER II

THE CHANGING CLIMATES

OUR own knowledge of the so-called 'dry' summers is sufficient to prove to us the indubitable necessity of water for plant growth. Without this great world-requirement such growth is impossible, and without this fundamental aid all life that feeds upon it must be likewise lacking. Primarily water falls upon the land in the form of rain and snow, and whether that water drops earthwards upon the home region or comes in the shape of rivers rising in distant highlands, the result is the same—namely, that with it agriculture is possible, and without it man can only sustain life at the expense of having his food sent to him from elsewhere. In a truly *agricultural* nation, industrious so far as the factors of climate will permit, there must be a marked relationship between the rain that falls and the population statistics. In India this relationship is so simple that the rainfall and population maps, built up upon any shading or colour scheme, may almost be interchanged, so closely does a heavy rainfall correspond with a large population,¹ and a slight one with a proportionately poorly peopled area.

The dependence of food supply upon rainfall and hence of population upon rainfall must have been no less true among the earlier peoples, but the inquiry as to where they congregated and what they did leads to several very significant discoveries.

In the first place it is obvious that many ancient centres,

¹ Especially is this true of the Indo-Gangetic Plain.

the nature and extent of which indicate forms of human activity ranging from life under conditions of considerable difficulty to that in a highly organized society, are now almost entirely or completely deserted. Great civilizations such as those of Mesopotamia and the Mediterranean lands, for example, have either disappeared or woefully degenerated. On the other hand, there is much evidence tending to show that even during the historic period different areas of the world's surface have been subjected to great climatic changes. It remains to be considered how far, if at all, these two phenomena are connected.

Partially or entirely deserted settlements are generally to be found in parts of Asia, Africa, and North America where to-day the water supply is quite inadequate for the needs of the crops that must have been necessary. This is the case in Palmyra (Syria), which in the time of Ptolemy contained 'abundant and sweet water,' a legend confirmed by the present existence of eight large, ruined conduits. Elsewhere, as in the case of the road from Petra to the Persian Gulf, owing to lack of water former famous routes have fallen quite out of use.

Saharan excavations point to the same conclusions. It is unlikely that so practical a people as the ancient Egyptians would build cities right out in the perfectly dry Desert; and even granting that they owe their ruin to wind-blown sand, former water possibilities which have apparently vanished must be assumed. Additional examples of climatic change are furnished by the valleys of the Iran Plateau; they contain numerous ruins of fortifications, reservoirs, and traces of irrigation ditches, presuming an extensive cultivation of the fruits of the earth, carried on by a formerly large population which it appears improbable the present conditions of climate could support.¹

¹ The present streams are intermittent and often salt; once they must have been perennial and fresh. But see also page 101, footnote, for another explanation of this decay.

The desolate region of Lob Nor,¹ in Central Asia, contains ruins of oasis-towns, some of which possess such numerous and commodious religious establishments and irrigation works that again a former and considerable agricultural population must be presumed. Chinese traditions, and the nature of the sand mounds that have engulfed the still existing trunks of the dead tamarisks, give at least one date for their abandonment as social communities, and the nature of one catastrophe that overwhelmed them—desiccation.² Examples of this desiccating process are not lacking in the New World. On the terraced walls of the great cliffs of Arizona, that region of the Colorado Cañon described as the “land that God forgot,” are ruins of the houses and gigantic palaces of a long vanished people. The stone work of miles of choked irrigation canals prove that here, at some remote period, fields waved with golden harvests, where now the desert, with its waste of rock, sand and salt occasionally broken by giant cacti, the yucca plant, and the tarry-smelling creosote bush, reigns supreme. Elsewhere in Arizona and the equally arid districts of New Mexico, ruins of temples, ancient *pueblos* or communal houses, walled fields and pottery remains indicate an early people practising an agriculture far in excess of that possible at the present time.

The climatic change involved in the foregoing instances is one of desiccation, but sometimes the reverse process has taken place and with equally disastrous results. Thus, half buried in the bush and jungle of Yucatan and the Maya Lands of Central America, are the ruins of magnificent temples and other buildings whose architecture and ornamentation are of so superior a character that a place among the highest of the extinct civilizations of the continent is claimed for that which produced them. Here it seems probable, judging by the devices for water storage, that less rain fell

¹ Or “Lop Nor.” Both spellings are in use.

² Huntington (*Climate and Civilization. Palestine and its Transformations*).

formerly than at present, making of this region—to-day rather renowned for its fevers and enervating heat—a more or less open but decidedly healthy parkland.

The Old World, too, shows regions where drought necessitating irrigation is a thing of the past. In Central Asia, for example, there are unused irrigation canals on the slopes of the Kok-tal Range in the Kirghiz cattle region which are not to-day conspicuously dry.

Such evidence as this must lead to the conclusion that there have been certain great climatic changes in operation during the human period whereby lands moderately or even adequately watered have become arid or desert, though occasionally the change has been in the direction of a much heavier rainfall.

In the cases just described it may be supposed that progressive desiccation (and perhaps excessive humidity) has brought about the gradual or partial extinction of the races experiencing it. They have either vanished or left architectural and other remains so defaced by time that it is now difficult, if not impossible, to trace their development.

However, there is allied evidence of climatic changes in the movement of tribes impelled to leave their homes under what may be described as the 'hunger urge,' a phrase which explains itself.

The years 2500 to 400 B.C. are marked by the continual rise and fall of ancient civilizations in the East, in each case the ruder tribes attacking and conquering a more peaceful and prosperous neighbour, to become themselves peaceful and prosperous and to undergo subjection in their turn.

Thus about 2500 B.C. the Shepherd Kings of the Hyksos Dynasty moved into Egypt from the semi-arid plain of north Arabia,¹ an invasion probably due to food scarcity. Some centuries later famine in Canaan drove the sons of Israel to seek 'corn in Egypt.' Not long afterwards—

¹ It is assumed that the Hyksos kings came from Arabia (Myres: *The Dawn of History*. Flinders Petrie gives 2600 B.C. as date).

apparently seven years—the drought had extended into Abyssinia, causing diminution of the water supply to the head-streams of the Nile, and consequent failure of the annual floods—thereby producing the famous Seven Years' Famine in Egypt itself. During the four succeeding centuries the Assyrians descended from their barren uplands to the fertile plains of Mesopotamia, at first destroying the agricultural Empire of Babylon, then, later, as Babylonia itself began to feel the effects of the spreading drought, passing on to conquest farther west. The activities of the Medes, Persians, and Greeks, culminating in the adventures of Alexander, may likewise be explained as the more or less direct consequences of the movements of people due to the hunger urge.

Perhaps the invasion of our own country by the bronze-working and Belgic Celts (c. 1200 B.C.¹ and c. 250 B.C.) are indirectly episodes belonging to the same great tribal migrations.

During the two centuries before and after the Christian Era no great movements of people took place. They were occupied by the extension of the Roman Empire, giving good government, peace, and prosperity to the lands that gradually came under its domination. Based upon and supported by agricultural wealth, this Empire was necessarily of a military character. But though it is generally held that prosperity brought into the national life an enervation which reacted adversely upon its military ardour and capacity, it is more probable that the Roman Empire fell before a greater fighting force than its own sword and its own ordered legions. The third century was well upon its way when the 'Barbarian' migrations began. Their immediate cause seems to have been the blows struck by the Asiatic nomads upon the settled races of Europe. The

¹ Dated variously. H. J. Fleure (*The Races of South Britain*) gives about 1150 B.C. for the arrival of the Bronze-working Celts on the east coast of Britain. C. E. P. Brooks (*The Evolution of Climate*) gives 1800 B.C.

attack delivered upon their eastern frontier was transmitted westward from tribe to tribe, and the history of Europe during the third, fourth, and fifth centuries is filled with the westward and southward sweep of these raiding hosts, and the great slaughterings and exterminations that resulted from their battles. The confused records of this period involve the initial descent of the Teutonic Races on Britain, the spreading of the Franks and Suevi respectively to North and South Gaul, of the Burgundians to the Saône-Rhône valley, the push of the Vandals across the continent to Andalusia, and the migration of the Visigoths from the Danube Valley, at first to the East Balkans, and later, under Alaric, to the attack and sack of Rome (A.D. 410). Through the dim mist of the past can be discerned a Europe in perpetual turmoil, a fitting prelude to the oncoming of the Dark Ages, which may be said to have begun when the Roman Peace gave way before the Sword of the Hunger-God.

In the ninth century there was another great movement of tribes originating in the Far Steppe of Central Asia, whereby hordes of pastoral, but otherwise fierce and warlike nomads fell upon the dwellers in the rich river valleys, setting in motion the various Mongol invasions of China, Russia, and even Hungary, and without a doubt powerfully stimulating those 'barbarian' movements still further west that caused, among other reasons, the downfall of the Empire of Charlemagne. Four centuries later this story was repeated, when the East European Plain came under the rule of Jenghiz Khan.

It has already been hinted that these epoch-making migrations were probably due to the 'hunger urge' arising from a food scarcity consequent upon an adverse climatic change. This supposition receives remarkable support from the geographical evidence regarding the shrinking and expansion of lakes or inland seas. Lob Nor in Central Asia, the Caspian and Dead Seas in the Nearer East, are striking and

sufficient examples in the Old World : Lake Mexico provides an analogous example in the New.

The evidence concerning the Dead Sea is based upon the presence of certain 'beach terraces' that occur on its margins, and certain Biblical records and legends handed down by the early Christian Church. From geological considerations it results that the shore line (beach terrace) has not always been at the same level, while historical and traditional records bring out the fact that the changing beach has several times stood higher and several times lower than some previous standard.

Crustal movement involving an uprising of the surrounding cliffs, thus bringing to light former beach floors which might have been *formed* at the same height with reference to the usual standard of sea level is not possible here, owing to the undisturbed state of the horizontal strata, which such movements would at least have crumpled or distorted, and the observed phenomena can only be satisfactorily explained on the basis of a varying depth of water in the lake, due to a varying rainfall at the source of the Jordan or in its catchment basin. The Biblical accounts of the Dead Sea in the times of Joshua and of Christ point to a level of water differing greatly from that of the present day. Thus at the Baptism of Christ (A.D. 30) the Sea stood high ; at least the traditional spot at which it took place is now well above the level of the lake. Between the years A.D. 150-250 numerous Roman baths in Palestine imply conditions decidedly humid, though about a century later the Dead Sea was apparently as low as at present, which we know represents a dry era. Two centuries later there was more bath-building, followed, according to the not very reliable evidence of Gregory of Tours, by ten years of increased aridity. At a later date (A.D. 712-50) the Arabs built large baths out in the Syrian Desert, implying a return of a moister climate.

The fluctuating level of the Caspian Sea is sufficiently proved not only by the presence of 'beach terraces' and

traditional or documentary records, but by the remains of ancient buildings of known age, some of which—to-day high and dry—show incontestable signs of a former submergence and others of which can be seen through the still water to have been erected upon what were once at least dry banks. Without going into details and statistics it is here sufficient to state that several times the surface of the Caspian, like that of the Dead Sea, has stood higher and several times lower than at present.¹

The lake of Lob Nor, in the Tarim Basin, has a history similar to that of the Caspian Sea. According to Chinese records, during the early years of the Christian Era this lake was smaller than at present, but it so greatly expanded in the second and third centuries that certain village sites near its margin had to be abandoned. During the fifth and sixth centuries the lake shrank once more, and the former sites were reoccupied, this experience of flooding and emergence being subsequently repeated. They are at present again abandoned—not this time through overflowing water, but on account of the desiccation of the region, which renders human habitation impossible.

Now when the statistics concerning the movements of peoples and the drying up or shrinkage of great water areas are examined, a singular relationship comes to light, namely, that *generally* high water levels—a condition implying considerable rainfall—in the Dead, Caspian, and Lob Nor Seas, or the digging of baths in places at present desert, corresponded to periods when the movements of peoples were not in operation; whereas, on the other hand, low levels of these great inland waters, implying aridity of the surrounding countries, corresponded to epochs of widely extended tribal movements, which received their initial impulse from the desiccated regions affected.

¹ Huntington disposes of the view that the change in the level of the water might have been due to a change in the courses of the Amu- and Syr-Daryas (*The Pulse of Asia*).

The rings formed by trees during growth have also been pressed into service for the purpose of calculating periods and even years of drought or special humidity. From autumn to autumn may be taken as a true 'tree year.' Should there be drought in spring double rings are formed in the tree trunk as expressive of an omission of cellular tissue between one ring and the next. Now the food supply for trees depends upon moisture, especially when the quantity of moisture is limited and the tree is battling against drought rather than rival vegetation. In regions where this latter is known *not* to be a feature, the presence of cellular tissue between the rings can be used to deduce a measure of the precipitation.

The typical American investigations dealing with this subject were undertaken by A. E. Douglass, of the University of Arizona, for the trees of Arizona, and by Ellsworth Huntington and his assistants for the giant sequoias or 'big trees' of California, many of which are two and even three thousand years old.

Correlation of their results with those of other and similar investigations carried out elsewhere have led Huntington to the belief that important climatic 'pulsations,' lasting one or more centuries, have been in progress throughout the historical period at any rate, and that climatic pulsations (that is, a rising to a maximum of humid conditions followed by a decline) in Western America, and similar latitudes in Western and Central Asia are possibly contemporaneous and of the same type.

The validity of these deductions as regards periods of climatic change was tested and checked by reference to the shifting level of Lake Mexico, for which there is historical evidence in the shape of dyke and tunnel building. Thus during the earlier part of the fourteenth century the Californian trees were growing rapidly, but in this respect the succeeding two hundred years showed a decline. From 1500 to 1700, approximately, growth was again rapid.

Between 1490 and 1610, and again in 1620, there were inundations so severe that a tunnel had to be constructed to carry away the surplus waters. Further extensive flooding and consequent increased pressure of water damaged this tunnel considerably in 1675.

That high water in the Lake (in reality a group of lakes) corresponds fairly closely with years of rapid growth in the Californian trees is thus well-established for modern times, and the principle of climate involved may rightly be extended to cover similar phenomena of more ancient periods.

Making the necessary allowance for latitude, it appears extremely probable that when winter rainfall increased in the zone of the prevailing westerlies, and hence affected the so-called Mediterranean climatic region of California, the summer rainfall increased on the borders of the Tropical Zone, causing among other results extensive flooding of the lakes upon whose banks Mexico City is built. Taken together, the evidence at least points to this—that there have been changes of climate (regarded by some investigators as pulsatory or fluctuating) during the human period and of wide territorial extent.¹

¹ There is no historical evidence in North America of *great* tribal movements comparable to the Barbarian migrations of Europe, but perhaps the rise and fall of the Mayan Civilizations really come into this category. The remains of buildings, temples, and water-storing tanks point to at least two "great" periods, separated by a long period of decline. The same means are not available for dating these epochs of splendour, such as exist, for example, in the case of the Pyramid Age of Egypt; but if the decline of the Mayan Empire were really a consequence in this tropical area of an excessive rainfall, their "great" periods should correspond to times of slow growth of the Californian trees, and the shrinkage of those lakes upon whose banks Mexico City was subsequently built. The destruction of the peaceful "Mound" Indians, farther north of a region of unfavourable climate, may be of an allied significance. Huntington, however, makes his hypothesis of a southward shift of climatic zones the basis of a precisely contrary argument (*The Climatic Factor*).

Confirmation of this assumption is also supplied by that geological phenomenon termed a 'river terrace.'

The mud or silt carried by a river may be deposited as a sediment upon its bed when for some reason or other the speed of the water is checked. The level area on either bank which receives this sediment during flood is the 'flood plain.'

The more rapid the stream, the more sediment it can carry, and the deposition of mud and sand on the riverine lands is due to the rising of the stream above its banks, and consequent checking of the speed of the waters as they become spread out over the neighbouring levels. Of course, a river carrying much sediment might deposit the major part of its load if an earth movement of the nature of an uplift decreased the slope of the river bed, hence reducing the velocity of the stream. Such a cause of terrace building would be traceable in the contortion of the strata below the deposited alluvium, since distortion or warping always accompanies a crustal uplift. The cases to be considered are those in which the horizontality of the strata proves such uplift not to have taken place.

Under normal conditions all streams are engaged in broadening and slightly lowering their valleys, the main stream forming the flood plain, and the tributaries giving rise to the type of surface described as 'rugged.' During a relatively moist period the hills or mountains of a given region may be covered with forest or other vegetation, while numerous streams, running off the highland, and with a regular and efficient water supply, discharge their silt-laden waters into the main streams, which in their turn bear this sediment to the sea. When these conditions are altered, aridity replacing humidity, the forest and vegetation necessarily die, thus depriving the soil of its protection, and the streams diminish in volume, many of them only succeeding in reaching the main rivers in times of exceptional flood. Such mountain streams as exist thus become doubly over-

loaded, and where the gradient is less steep, as at the mountain foot or in the larger valleys, deposition of this heavy load takes place. The result is a deep accumulation of gravel and sand fanning out from the mountain foot (the 'alluvial cone') or the building up upon the valley floor of a gently sloping plain of the same material as the stream, in its migration, wanders from side to side.

On a return to moist conditions the revived stream now reaches the main river or the sea, but on its journey, by virtue of its increased volume, it cuts deeply into the accumulation of porous gravel and silt, and as it is no longer an agent of deposition, but one of erosion and transport, it carves a deep bed in its former 'flood plain' and so forms a terrace on either bank.

The meaning, therefore, of the presence of a river terrace of this character on the banks of a seaward flowing stream is that at some time or other the region in question underwent a lengthy period of profound drought followed by a period of greater rainfall, for in no other way than that described above can its formation be explained where horizontality of strata shows there has not been crustal uplift. Moreover, in southern Arizona, an admittedly arid country, terrace making appears to be in the process of formation at the present day, and by such a method as has been just described.¹

Now these terraces—often called 'river drifts,' sometimes discovered on the surface and at others brought to light through excavations—frequently yield human remains in the form of implements, etc., in such a position and in such a quantity that it cannot be supposed that they have worked their way through the soil, but rather that the terraces containing them and the implied aridity of climate are features of the 'human' period.

Whatever its precise nature, this shifting of climatic zones, whereby good, bad or indifferent conditions of living

¹ The above geological explanation of the formation of river terraces is that put forward by Huntington (*The Climatic Factor*).

have alternated in any one area is not merely of historic significance. That which has been may yet again occur. A point of interest lies in the fact that in the sub-tropical countries the national prosperity of the highest civilization to which the region could give rise went hand in hand with successful irrigation.

NOTE ON THE DESICCATION OF ASIA

Whether the 'heart' of Asia is truly 'drying up,' or whether the climatic changes which have occurred in the centre of the great continent within the human period have only been slight, is a matter still in the controversial stage. Ellsworth Huntington appears to give much credence to the desiccation process, based upon a hypothesis of periodicity, and supported in his estimation by analogies collected from other regions. Sir Aurel Stein (*Geographical Journal*, Vol. LXV, Nos. 5 and 6) suggests that the same effect might have been brought about by quite other causes. He instances the abandoned oases in the Tarim Basin, and points out that the extensive irrigation works of the character necessary in that locality must have required a great amount of labour to keep them in efficient repair. Prolonged periods of warfare or internal disorder, or devastation of the population by epidemics, might cause neglect of the canals and reduction in the labour supply. In some cases the changing of the course of a river bed at critical times might necessitate new canals if irrigation were to be maintained. Finally, certain tracts of abandoned territory lie on an ancient caravan route connecting oases widely separated, and Sir Aurel thinks it possible that the smaller oases upon this route may have been beset by wandering tribes without being in the position to protect themselves, or that mere disuse of the route may have been a potent factor in their decline. These two suggested causes could, of course, be simultaneous and connected.

Sir Aurel Stein also quotes the interesting hypothesis of Sir Sidney Burrard. The streams running into the Tarim Basin are fed from glaciers on the surrounding heights. These glaciers may possibly be a remnant of the last Ice Age, and consequently have been gradually shrinking ever since the climate began to 'recover.' This means that there is no longer the same amount of water at the source of these rivers as there has been in the past, and would account for the failure of the supply without involving any serious theory of desiccation. On this hypothesis 'pulsatory climatic changes' would explain the varying volume of the rivers as an expression of the varying rate of melting of the glacier ice.

BIBLIOGRAPHY

- ELLSWORTH HUNTINGTON : *The Pulse of Asia* (Constable).
ELLSWORTH HUNTINGTON : *The Climatic Factor* (Carnegie Institution, Washington).
ELLSWORTH HUNTINGTON : *Civilization and Climate* (Oxford University Press).
ELLSWORTH HUNTINGTON : *Palestine and its Transformations* (Constable).
E. HUNTINGTON AND OTHERS : *Evolution of the Earth and its Inhabitants* (Oxford University Press).
E. HUNTINGTON AND S. S. VISHER : *Climatic Changes* (Oxford University Press).
W. M. FLINDERS PETRIE : *Egypt and Israel* (S.P.C.K.).
C. E. P. BROOKS : *The Evolution of Climate* (Benn).
SIR AUREL STEIN : *Innermost Asia* (*Geographical Journal*, May and June, 1925).

CHAPTER III

GENERAL METHODS OF IRRIGATION

IRRIGATION is the process of supplying water to waterless regions. Irrigable soil is of two kinds. The first is that which is found in the neighbourhood of rivers, and consists of accumulations of sediment which they and their tributaries have brought from distant highland. The sources of these streams are often located in mountains or hills of very different mineral characteristics, so that the sediment, besides being finely grained, may be composed of many varieties of rock waste. Silt of this description is exceedingly fertile, and upon it can be grown rice and other vegetable products that require a rich soil food. The exhausted soils are thus annually restored by the rivers' floods, and one might be tempted to ask what need is there for irrigation in such lands, but for the obvious fact that crops cannot be grown in flood time.

The second kind of irrigable soil is 'desert soil,' to which water must be brought artificially from long distances.

The flood alluvium, or river silt, brought down by the Nile in Egypt, the Euphrates-Tigris in Mesopotamia, the Yangtze-kiang and Hwang-ho in China, the Ganges and Indus in India, furnish examples of the first type. It was upon such lands as these that agricultural communities whose wealth and progress depended on the success of their irrigation took their rise, and it seems reasonable to suppose that the regularity of the annual floods first gave the riverine population the idea of 'catching the flood waters' for these purposes. A bigger flood than usual would fertilize and

moisten more land, and as the waters subsided much of it would collect in the inequalities of the ground, and, wherever the clayey nature of the soil caused it to remain, vegetation or crop growth beyond the strict limits of the normal flood water would be bound to benefit. The digging of trenches in delta lands or other suitable localities along the river banks would follow naturally through mere imitation of nature's methods, and that these were nature's methods appears to be borne out by the story of the Garden of Eden. Whatever may be its true significance, it is at least clear that Eden represented some oasis of fertility watered in this manner. "A river," states the narrative, "went out of Eden to water the garden," and though the 'four heads' may be the two separated streams, which at that time flowed to the Persian Gulf without uniting, and some now lost tributaries, it is noteworthy that there is not the slightest reference to any human agency as engaged in the work of digging water-channels from the main streams. The soil of the Garden was presumably moistened by seepage from the water courses, or by the evening mists which evaporation during the great heat of the day would originate, or by a combination of these two processes.

The civilizations which anciently flourished in regions of this character are those belonging to Egypt, Mesopotamia, China, and Northern India. The mere watering of the crops was but a small part of the benefit accruing from this kind of labour. To give appreciable results the work must be well done, and though the harvest gives a great reward, equally great is the work of preparing for it. The building of dams, the digging of ditches and trenches, require so much labour that it is quite worth while to keep them in repair. Where water is so valuable, economy in this one particular at least may be confidently expected. Interruption in the regulation of the stream and its distributaries may well result in total ruin to the crop, and a non-interruption implies the internal peace of a well-organized

government, especially in such regions where the agricultural population is large, owing to the quantity and quality of the irrigated product as a food. All these are fundamentals and necessities in such systems of civilization, which must look back as ultimate origin to the practice of irrigation.

In point of historical sequence the 'terrace cultivation' of Arabia provides a link between the channel and ditch irrigation of the riverine and deltaic lands dependent on the long rivers of the Orient, and that carrying of water to the purely desert soil which is becoming so prominent a feature in the development of arid America and Australia.

Terrace cultivation was a necessary consequence of the configuration of Arabia, if cultivation were to be undertaken at all. Arabia consists largely of an arid central plateau flanked on the west by terraces falling seawards, which are crossed in certain favoured localities by rapid, if intermittent, torrents flowing in deep, cañon-like beds. The problem was how to hold back this water so that it could be utilized to the greatest advantage before reaching the sea, and the problem was the more urgent as a few days of tempestuous flood torrents were inevitably followed by long periods in which the river beds were waterless. The method evolved consisted of damming back the streams near their source. The land to be cultivated was levelled into terraces separated from each other by loose stone walls of a height varying from 5 to 10 or more feet, each wall being approximately level with the upper terrace. The cultivated slopes therefore appear as a somewhat irregular stairway.

The water, liberated at the top terrace, flowed into and over it, and so down the hill or mountain slope, irrigating terrace after terrace, whose surfaces were furrowed by a crude form of harrow which enabled them to retain much water after the main outpouring had passed. Collected at the base of the slopes the water was led over the plain at their feet by a system of irrigation ditches, so that cultivation here also was possible.

In Yemen (south-west Arabia), which now possesses a climate much drier than formerly, there are remains of a number of huge irrigation dams. One of these, 2 miles long and 120 feet high, was built about 1700 B.C. After the death of Mohammed (A.D. 632) the Arabs, filled with proselytizing zeal, spread eastwards to Baluchistan and the Indus valley, carrying alike their religion and their irrigating skill, to which latter the marvellous ruins of their water storage works amply testify. Westward, North Africa and Spain fell under their subjection, and the terrace and *huerta* (garden) cultivation in these districts is substantially the same to-day as when first instituted by the Arabian (Moorish) conquerors of these territories.

It is a far cry from the terrace cultivation of Ancient Arabia to the Desert Reclamation of the Western United States. Here, out in the Desert, even the torrents are generally lacking, and where they exist, as in the cañon countries, the rivers flow in steep and narrow beds from 1000 feet to a mile below the surface of their banks—much too deep for their waters to be available for the irrigation of the riverine lands. But America is a country of great ideas and equally great accomplishments. To these deserts of the West, threaded by useless streams, water is being brought either by the ancient process of controlling some suitable river or by transportation over enormous distances in concrete-lined ditches.

The soil of this desert, though renewed by no annual flooding, is not infertile. Derived from rock waste and spread out in vast plains by wind action, its mineral constituents make an excellent plant food, and only the solvent influence of water is required for rendering these constituents effective to bring the land into line with other agriculturally productive regions. Perhaps this is somewhat overstating the case, however; some deserts need more than the magic touch of water to make them 'blossom,' and from time to time there must be deliberate addition of an ingredient

which plants absorb from the soil, and which in these cases is not renewed by natural means. This is nitrogen, very necessary to the growth of vegetation, abundant in the atmosphere, but only entering with difficulty into chemical combinations. Nitrogenous manure (guano or natural nitrates) and in more recent times artificially manufactured compounds of nitrogen are extensively used for this purpose. The same result, however, can be obtained by the growing of certain crops, among which lucerne, or alfalfa, takes a pre-eminent place. Like other members of the pea family it possesses the power of 'fixing' nitrogen, that is, of abstracting that gas from the atmosphere, and elaborating it into a form (or compound) in which it can be restored to the soil. This it does by the agency of certain bacteria which attach themselves to the rootlets of the plant; moreover lucerne is capable of thriving in a somewhat alkaline or salty soil. With the modicum of water which can be brought to it artificially it not only restores the needed nitrogen, but is in itself a highly nutritious food for livestock. Besides supplying food for the farm hands, the keeping of cattle has the further advantages of providing another source of manure for the soil and a means of transport necessary in certain farming operations.

As a consequence of the high amount of sunlight natural to these arid lands, the harvest may be gathered several times a year and the yield is heavy. On the enriched soil fruit trees or other crops are planted later when the land has been well irrigated. Where the luxuriance of the irrigated crops tends to rob the soil of its nitrogen content, a further sowing of lucerne will restore the lost ingredient.

The semi-arid lands of North America and the Union of South Africa, where the rivers flow in cañons so deep that soil renewal through silt-deposition is impossible, use this crop lucerne as the basis of all the desert reclamation. The history of its gradual adoption as a main crop is exceedingly interesting. Long ago its value was known in northern

Africa, and ultimately the Moors introduced it to Spain. It arrived in South America through the agency of Spanish missionaries, who planted it first in Chile, but it was not until the nineteenth century that 'alfalfa' (*Arabic*: al-faṣṣaḥ = good food), as it came to be called, was cultivated in the United States. In this case, also, its introduction was due to the zeal of Spanish missionaries.

In the Union of South Africa the principal impetus to lucerne growing was the expansion of the ostrich feather industry, and, later, the expansion of pig farming. Irrigation schemes for growing it were not put into operation until 1912.

'Oasis Irrigation' may be regarded perhaps as a special instance of one or the other of the foregoing methods. Here the river is under rather than upon the surface, though Egypt is regarded as the oasis of the Nile. Oasis irrigation, which is a feature of the Desert, is sometimes effected by what is known as 'artesian water.'¹ This term may be explained as follows. Two contiguous strata of rock, the upper one porous and the lower one non-porous, are folded into a species of gigantic basin. When rain falls upon the basin rim (here the highlands girding the Desert) it passes away underground and ultimately collects in the trough. This water may saturate overlying sand and be obtained by the simple digging of wells, but if it be overlaid by another non-porous stratum the water is artesian, and may be recovered by sinking a pipe or shaft through the upper impervious layer. The pressure on this water depends on the height of saturation of the porous layer above the surface of the reservoir, and when it has been 'tapped' in this way it rises in the shaft. In former days when such wells were dug water gushed out, but nowadays

¹ But see also page 193, where the origin of the so-called artesian water of Australia is discussed. The name is derived from the Province of Artois, in northern France, where this method of recovering underground water was first extensively studied.

the issuing stream is controlled so that it can be made to flow at the times and in the quantities required. If the pressure on the water be insufficient to bring it to the surface, it may have to be lifted by means which are often laborious. It is then led into irrigation ditches or canals. Where through the inequalities of the buried floor underground water is brought within reach of plant roots a 'natural oasis' may result.

It is convenient to defer detailed consideration of the actual methods by which the irrigated crops receive their water until they can be discussed in connection with the various localities in which they are practised. However, a few very general remarks upon this subject may not be out of place at this point.

Given a source of supply, whether flood or storage water, whether lifted from a river or from a well, the ground intended to receive it may do so by one or other of four ways, or by some combination of them.

For basin irrigation the land is parcelled out by low embankments of earth and inundated, the movement of the water to and from the basins being directed by the making and the breaking of temporary dams in these walls. In the case of the Nile floods, large areas were and are completely inundated by the rising of the stream, the waters being allowed to lie for about forty days, after which they are drained away through notches cut in the basin walls. Irrigation by gravity is the term in use when streams, runnels, or trickles of water flow down sloping ground. These are fed in the first instance from some such source as a canal taking water directly from a weir or river and at a higher level than the area to be irrigated. Here, too, temporary banks and dams may direct the flow. Terrace irrigation is a variety of irrigation by gravity as it is effected by falling water. The general method of its employment has already been considered, but the practical details differ slightly in the different countries. In Arabia the source of the

irrigating flood lies in the rains of the south-west monsoon ; for some of the terrace cultivation of China water may have to be lifted from below by a succession of water-wheels. These cultivated shelves may be wide and shallow, or narrow and high, etc.

In some hot lands water from wells or reservoirs is poured directly upon the growing crops. Lastly, water trenches, however filled, may be so close together that the soil between them receives adequate moisture by seepage. As already pointed out, evaporation and mists may play their part in this case.

BIBLIOGRAPHY

- G. CHISHOLM : *Handbook of Commercial Geography* (Longmans).
D. G. HOGARTH : *Penetration of Arabia* (Alston Rivers).
UNION OF SOUTH AFRICA : *Official Year Book*, No. 4. (1910-20.)
No. 7. (1910-24.)
M. I. NEWBIGIN : *Tillers of the Ground* (Macmillan).
J. BRUNHES : *Human Geography* (Harrap).

CHAPTER IV

SOME ADVANTAGES OF IRRIGATION

THE ground having been prepared by bringing the water to the thirsty soil, irrigated crops and fruits appear to possess certain advantages over others raised without this artificial aid. Both the yield per acre and the quality of the product are greatly increased. The reason for this superiority is obvious.

To begin with, the water supply is regular, and can be given as required. The crops are neither over-watered nor allowed to get too dry. Not only is the farmer *not* at the mercy of the weather, being sure of a sunny harvest time, but he is enabled to grow a greater variety of products in rotation, to the enrichment of his soil. Especially is this the case in the newly irrigated lands of North America and Australia, where there is no tradition similar to that of the Orient for grain and rice.

As has been already noticed, the irrigating stream often contains fertilizing ingredients. In India irrigation doubles the weight of harvests off the same land. In America, where irrigation on the large scale of modern methods is still in its infancy, especially in the hitherto never irrigated lands of Alberta (Canada), the soil has not been exhausted by centuries of farming, and the nitrogen deficit can easily be made good by alfalfa. In some countries, however, the flowing of these artificial rivers does much to prepare new lands for agriculture by washing away certain injurious constituents of the soil. This is especially the case with the 'brak' soil of South Africa.

On the other hand, the soil of an arid country is often

exceedingly fertile, for in the absence of rain its soluble constituents have been preserved.

Another advantage lies in the great variety of crops that can be cultivated in close neighbourhood, since soil and temperature are the main factors to be considered. Forage grasses, cereals, tree and other fruits, both warm-temperate and tropical, supply the demands of many diverse markets so that good monetary returns are always assured. Allied to this is the replacement of wild plants by edible varieties, and it has been found that all crops, whether of grain or rice, forage or fruit, grow the better the further they are from the equator as long as there be sufficient sun to mature the harvest. The lengthened daylight in each period of twenty-four hours is responsible for this phenomenon to which, of course, cloudlessness must contribute.

Provided the temperature be suitable, irrigated agriculture may be carried on continuously, thus avoiding periods of enforced idleness. Further, when only a short interval separates planting and harvest, the same piece of irrigated ground may nourish successively several crops in a year. Thus, in the arid states of California and Arizona market garden produce can be planted at almost any time and five annual cuts of alfalfa are customary from one patch of land.

Irrigation in the droughty regions of North America and Australia which are being developed by some of the surplus population of the homelands possesses certain advantages on the social side. The labour and consequent intensive cultivation necessitate a "closer settlement" of the agricultural population than is possible in a merely pastoral district, thus increasing the enjoyment of community life. The absence of rain makes primitive roads capable of standing the heavy farm traffic, while the system of crop rotation prevents monotony of labour and so encourages long residence, the irrigated farm becoming for its owner "a home, and not a halt" on his path to wealth.¹

¹ Handbooks of the Canadian Office.

PART II
IRRIGATION OF THE ANCIENT WORLD

CHAPTER V

IRRIGATION EMPIRES OF THE ANCIENT EAST

1. EGYPT

EGYPT consists of two distinct regions—anciently known as Upper and Lower Egypt—both situated in the Valley of the Nile. Upper Egypt extended from the First Cataract (Aswân) to Memphis (Cairo), and Lower Egypt from Memphis to the seaboard. The latter region was therefore the delta of the river.

The northern part of the valley of Upper Egypt is hemmed in by limestone cliffs; the southern by cliffs of sandstone. The valley is nowhere more than 15 miles wide and may be less than two. A granite sill closes it to the south, and here the rapids of the First Cataract formerly shut off Egypt from the wild tribes beyond.

Lower Egypt is typically deltaic, with a natural vegetation of reeds and bulrushes, and threaded by sluggish, distributary streams. The physiographic diversity for some time kept apart the Red Crown of the Delta and the White Helmet of the Valley Princes, but ultimately the unifying quality of the Nile, the unique source of prosperity throughout its borders, suggested and even necessitated political autonomy under a 'King of the Two Lands.'

The payment exacted by Egypt for its blue skies is the absence of rain; also dry northerly winds sweep regularly over the country.¹ Consequently crop growth has only been possible on the riverine lands reached by the summer

¹ The khamsin, a hot, dry south wind, blows during March and May.

overflow. The cause of the latter phenomenon lies in the monsoon rains experienced in spring and summer upon the Highlands of Abyssinia. For the moment further details concerning this seasonal rainfall may be deferred,¹ especially as the bare fact of the annual flooding probably satisfied the Ancient Egyptians.

The flatness of the valley floor meant an enormous increase in the harvest for a relatively small increase in the vertical rise of the water.

The simple folk who first inhabited this region lived in large villages which had grown up on the ribbon of land just beyond the flood level, and they were divided into tribes each with its own appointed district. The irrigation was really of the simplest character, but the mere continuance of cultivation would develop skill and bring about increasing harvests. Eventually aliens came in from the outer world, perhaps tempted by the obvious prosperity of the Delta, or attracted by rumours of corn in the Valley when famine was reigning elsewhere. Whether direct from the islands across the water, or creeping round Sinai by that *Way* later so familiar to the Philistines, or arriving from the Red Sea and the Kosseir Valley, certain it is that trade and raiders, bringing commodities and ideas, penetrated to the Nile Lands, to be followed by invading armies and attempted conquest. The first necessity would be for some man of discernment and courage to put himself at the head of the tribes, the better to organize a strong and common defence. In some such way the simple democracy of the tribal individualism gave place to a united people under a chosen native monarch, conquered more than once by an alien dynasty which succeeded in establishing itself at the point of arms.

It was under these early Dynasties that 'scientific' irrigation was evolved in Egypt. It consisted in the erection

¹ Light rains begin in April and reach the maximum in August (14 inches).—*Oxford Survey*.

of earthwork trenches for the *temporary* conservation of the irrigating flood. The system was taken under royal protection. The Bahr Yûsuf (or Joseph's Canal), marking the western limit of irrigation, was constructed as long ago as the First Dynasty.¹ It extended for 300 miles—one-half the length of the Upper Kingdom—from Abydos to the Fayyum depression.

The Government of Egypt was necessarily largely concerned with the 'land—or more correctly the water—rights, for upon their easy and just assessments the whole prosperity of the country depended. These rights and the corresponding estates were held by the territorial nobility, that is to say, the families of the powerful individuals who first secured them, or by the priesthood in trust for those gods whose malign influence in this country of pests, obnoxious flies, and vermin of various kinds, made propitiation a necessity. In course of time the proportion of sacred to lay property steadily increased since propitiation must never fail, and return from sacred to lay guardianship was as impossible among the Ancient Egyptians as with us before 1536. However, a former owner or his descendants might cultivate an alienated estate partly for his own profit.

Local courts dealt with local quarrels about water-rights, but appeals could always be made to the king, to whom the great land-owners were vassal, and it was clearly to the monarch's advantage to make such regulations as would prevent injustice to the cultivators—else must he suffer in his tax receipts! The 'Social Contract' in Ancient Egypt was thus based upon the certainty of the Nile's ever-recurring flood: "Give me of your land and your labour, and you shall have my water."²

But the Nile brought down something more than mere water. The 'slime and ooze' left by the subsiding flood is composed of fine detritus from the basaltic plateau of

¹ About 4000 B.C.

² J. L. Myres (*The Dawn of History*).

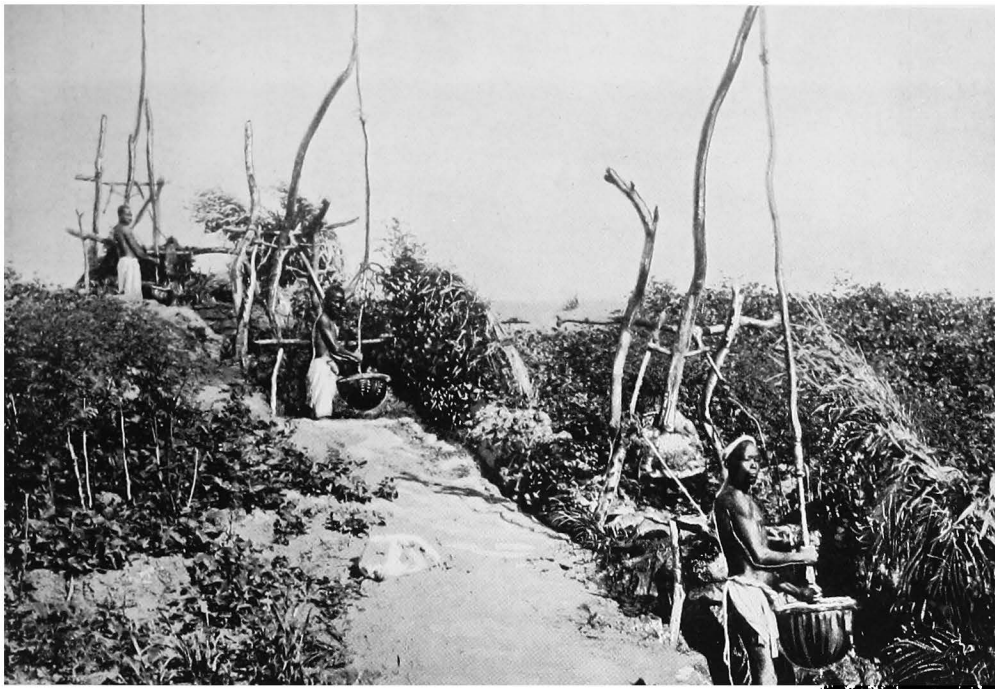
Abyssinia, and the quality of this silt may be gauged from the phenomenal simplicity of the seed-time operations—

“ the higher Nilus swells
The more it promises : as it ebbs, the seedsman
Upon the slime and ooze scatters his grain,
And shortly comes to harvest.”¹

It is said that the certainty of this ever-recurring seed-time and harvest made work an obvious duty, while the resulting reward and equally enforced leisure gave opportunity for activities of quite another kind. The sciences of astronomy and alchemy were practised by the learned, while the constant recurrence of the annual reward developed in men the hope of a future reward which naturally led them to an ideal of a life beyond this one. Thus the national monuments took the form of observatories, whereby flood and drought, seedtime and harvest, might be predicted, and since they were presided over by the priesthood, they were at the same time temples.

The neighbourhood of the Desert, the obvious demarcation between the fertile flood limit and the infertile sands, soon showed the importance of the Nile waters as the source of all productiveness, and an annual festival was instituted to commemorate the ‘ marriage ’ of the water with the earth, whereby the latter was enabled to bring forth her fruits in due season. For this bridal ceremony a female figure, modelled in clay and suitably adorned, was placed in the dry bed of Pharaoh’s Royal Canal ; the dam was then cut and the water, entering with a rush, bore away this ‘ earth-maiden,’ while the populace on the banks of the stream flung in offerings or ‘ wedding ’ gifts. In the course of centuries various myths arose to embellish this ceremony of simple origin, and notably among them is the legend of Osiris and Isis, whose union was thus symbolized.

¹ *Antony and Cleopatra* (Shakespeare).



Science & Art Museum

THE SHADUF WATER-LIFT

The height of the cultivated ground above the river here necessitates a series of three shadufs to raise it to the required level.

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Irrigation from the flood waters was a very simple operation, though in actual practice the riverine lands were divided by banks of mud into a number of connected sections or basins, with shallow ditches leading the water from basin to basin. In flood time the drenching of the soil was very complete, the submergence varying from 3 to 5 feet and lasting about forty days. As the flood subsided the basins were drained by a cut in their banks and a covering of fertile silt remained, though not till October or November was the ground ready for ploughing. Corn, pulse, cucumbers, melons, etc., formed a large proportion of the agricultural produce.

When the river was low in the hot season, water had to be drawn up from it to serve the hot weather or summer crops. This was accomplished by means of a *shaduf*. The *shaduf* consisted of a long pole balanced upon a beam supported by two columns of dried mud, wood, or stone. One end of the pole was weighted with a lump of mud, while to the other end hung a lighter pole to which a leathern bucket was attached by means of a rope of straw. When water was required the water-getter hung on to the pole-rope, which was thus lowered. When it was full he let go, and the weight at the free end of the lever did the rest. *Shadufs* were also used to fill the various channels away from the river where a rise in the surface necessitated it, water being lifted in this way from one trough to another. With a 'low' Nile several *shadufs* might be required to raise the water from the river to the 'riverine' fields.

The above form of apparatus was often replaced by the use of a *sakia*, or water-wheel. A wheel, supported horizontally, was made to rotate by means of a rope attached to a bullock or a man. The spokes of the wheel projected as cogs, and during revolution turned an upright wheel, provided with earthenware jars or buckets fixed to the rim. When the wheel was in motion the lower end passed into a pool or well, and was filled. When the jars were at the

summit of the wheel, the water was jerked into a trough from which the little channels could be supplied.

It is clear that water lifted by either of these methods must require excessive labour, with the result that the hot weather crops would not be cultivated to anything like the same extent as the winter ones.

2. BABYLONIA

Geographically Babylonia occupied the great deltaic region of the Rivers Euphrates and Tigris. The main part of their broad valley is built out of the wreckage of the highlands that close it landwards : at no great distant period, geologically speaking, it made part of a much extended Persian Gulf. Excessive weathering on the lofty Armenian Highlands and the Persian Scarp has provided material whereby the united streams have been enabled to advance their shore line at an appreciable but varying rate at present assessed at about one mile in thirty years.

In winter the snow lies heavy upon these highlands, and consequently the floods are enormous during the spring thaw. In addition to this source of water the 'Tigris-Euphrates Trough' enjoys a small rainfall, so that there is some natural steppe vegetation.¹ The Trough is subjected to a great annual range of temperature; Bagdad, not far from the site of ancient Babylon, has a January mean temperature of 49° F., and a July mean of 94°, while the temperature may fall as low as 20° and rise to 120°.²

Thus in the matter of rain and temperature there are essential differences between these and the Nile lands, where the winters are much warmer. There are other

¹ The rainfall of course is in winter. Bagdad has almost no rain from May to October, but its 'former and latter' rains amount to about ten inches annually, the latter rains being the heavier. Bushire, on the Persian Gulf, has fourteen inches of rain.

² It is convenient to defer further climatic details until the region is reviewed from the standpoint of the present time. See page 111 *et seq.*

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differences too, which express themselves in the different method of irrigation practised.

To begin with, Egypt was hemmed in by the Desert, and this permitted her early peoples to develop their social organization more or less unmolested. Here, the greenness of the steppe inevitably invited the excess population of arid Arabia to a region in which they and their beasts were very much at home, hence the several epoch-making invasions of the Semites. The hill-folk, too, from the Eastern Scarp-lands, were wont to make raiding excursions, and there was further contact with the outside world through the operations of trade, since the Trough was deficient in certain commodities which were not lacking in Egypt.¹ Thus the protection was not complete, but on the other hand, the influence of alien and virile blood more than once revived the Empire in periods of decline.

As in the case of the Nile, seasonal floods sent a great head of water down the valley, but the Euphrates-Tigris silt is much richer. It consists of an argillaceous sand or loam unusually rich in lime, nitrates and phosphates. The simplicity of the Nile alluvium is due to the single region from which it comes, for its equatorial contributory, the White Nile, flows through a great marsh or reed-grown lake, in which much of its load is deposited before its junction with the Blue Nile. The Euphrates-Tigris, on the other hand, rolls down the Trough like a river of liquid mud.

The system of irrigation here was not that of the basin type. Stone channels bore away the flood surplus, a work the more surprising since the country is deficient in this commodity.

Another difference consisted in a natural circulation of the water such as was not possible in Egypt. This is because there are two rivers instead of one, and owing to the difference in their respective speeds there has been a difference

¹ As, for example, stone, the only native building material possible being mud.

in the rate of silt deposition. Near Bagdad the Tigris flows over a bed at a lower level than that of the Euphrates, whereas near Basra the bed of the latter river is the lower. Consequently water can easily be made to pass from the Euphrates to the Tigris in one part of its course, and from the Tigris to the Euphrates in the other. In this way large tracts of country 'between the rivers' could be easily watered.¹

Lastly, there was the important fact that the flooding in Mesopotamia comes in spring (March to May); to avoid loss of water it is the *spring* floods that have to be dammed back. This necessitates more elaborate irrigation works than in the case of the Nile, but on the other hand, the main crops are hot weather or summer crops.²

The Babylonian irrigation was thus necessarily more elaborate than that of the Nile. This may account for the fact that a high state of civilization was reached in Mesopotamia earlier than in Egypt.³

In this favoured region, where tradition places the Garden of Eden, extensive and successful agriculture has thrice resulted in the growth of brilliant Empires.

The first of these was Babylon, on the Euphrates, located in the narrow neck of land between the rivers, where a network of canals converging upon it made the city, about 1000 B.C., the centre of one of the most renowned Empires of antiquity. The unfailing supply of water and the extraordinary fecundity of the alluvium caused, in the course of time, the rise of other cities near the capital, cities which sharing its water, perhaps contributed to its ruin.

¹ See page 97. Water is sent similarly from the Blue to the White Nile, but the process cannot be reversed owing to the slope of the land.

² Rice reached this region about 400 B.C.

³ Vidal de la Blache (*Principes de Géographie Humaine*) considers it inferior. He points out that the flow was less regular and the management uncertain. The Babylonians, he states, were incessantly preoccupied with bringing in foreign labour for the upkeep of their irrigation works and rural civilization.

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Nineveh, the capital of the second of these Empires, was situated on the Tigris a little north of its junction with the Great Zab. The productive advantages of the river, both for purposes of irrigation and soil renewal, were important factors in the development of this centre of great Assyria. The epochs of its glory were in the ninth and seventh centuries B.C., but since the fall of Nineveh irrigation has practically disappeared from this region, except in the neighbourhood of Mosul, where it lingers, a feeble simulacrum of its former self.

The last of these brilliant Empires may perhaps be regarded as inheriting the glories of Babylon. Its centre was Bagdad, one of the most magnificent cities of the Orient. Founded in A.D. 762, it rose to such importance that in the days of the Caliph Hārūn-al-Rashid the ancient irrigation works had been restored and the surrounding district revived for the past hundred years.

The destruction of the irrigation canals of Mesopotamia has been attributed to change in the course of the Tigris necessitating reorganization or repair which was not carried out. It is certain that during the Mongol invasions of the thirteenth century the head-works of the canals were destroyed, but in any case prosperity must have left the region when once it had fallen under Turkish control: "grass dies under the Turkish hoof" is a well-founded proverb of the East, and soon after that conquest (c. 1516) Mesopotamia rapidly passed out of cultivation. Now, for several centuries, widespread desolation has settled upon that land in whose gardens murmurous with flowing water the Lord once walked "in the cool of the day."

3. ANCIENT CHINA

Imperial China, like Mesopotamia and Egypt, was an agricultural Empire basing its wealth and progress upon the products of the field. It has been the custom since 2800 B.C. for the Emperor at the appropriate season of the

year to go out into the fields with his court and officials, and pronounce a blessing upon them, a sign of the high esteem in which crop-growing was held.

The irrigation works making this possible were often so enormous and so efficiently carried out that they have been in operation ever since, surviving the displacement of dynasties.

Previous to 300 B.C. irrigation in China was confined to the deltaic plain of the middle Hwang-ho. During this time and keeping step with its developing civilization those methods of spade culture, which to-day are regarded as characteristic of the Chinese people, were being perfected.

Perhaps the most celebrated of the irrigation 'projects' was the taming of the Min-ho and other affluents of the upper Yangtze-kiang drainage system, which was undertaken some time during the second or third century before the Christian Era. The river comes off the high Tibetan Tableland in a series of gorges cut through hard limestone rock, so that the water is torrential and totally unnavigable. Below this gorge region is the Red Basin, a term including the Plain of Chengtufu. By reason of its fertility this 'Basin' is frequently known as the *Garden* of the Province of Szechwan. The surface is low in comparison with the surrounding country, but by no means flat; and though diversified by mountains the general slope is from north to south. The soil is of red sand and clay of the Jurassic series—hence the generally adopted name. The highlands which constitute the *rim* of the Basin give it considerable shelter from the cold, continual winter winds, though at that season cyclones succeed in working into it from the Bay of Bengal, bringing with them their treasure of winter rain.

The slope of the land makes irrigation by gravity very easy, but before the water can be led off to the 'fields' the rapid pace of the natural flow has to be considerably lessened. Even in the dry season the Min-ho is torrential at Kwanhsien, where the works begin, by reason of the summer

thawing of the snow and ice of the high tableland, while at the height of the monsoon outpourings the river's great speed threatens to sweep everything before it.

It was between the years 250 and 200 B.C. that Li Ping, the Hereditary Governor of Chengtufu, conceived his gigantic plan and began the famous dyking, but the credit of its thorough and successful issue belongs to his son, Li 'the Second.' The work consisted of deepening and adjustment of a gorge above Kwanhsien, and the lateral spreading out of the mighty flood by division into innumerable channels. In this way the stupendous pace of the river was controlled, so that the waters could now be directed to the farmer's plots.

This operation necessitated the construction of strong barriers, dykes, and embankments, but as the original structures or their repairs form the basis of the present system, detailed description has been deferred to another chapter.¹

The gratitude of posterity took the customary Chinese form, and the two Lis became objects of pious veneration and worship. Near the gorge of Li II a temple, which is said to be the most beautiful of its kind in China, has been erected, and still proudly displays the image and motto of the illustrious engineer: "Shên t'ao t'an; ti tso yen"—"Dig deep the bars; keep low the dykes." This maxim, which signifies—keep the water at a constant level—has been faithfully and successfully observed for more than two thousand years.

In the thirteenth century of our era a provincial judge set on foot an extensive reparation of Li's works. He caused the dykes to be lined with quarried stone, the interstices to be filled with molten iron, and the whole structure to be caulked with a cement of lime and oil from the dryandra tree.

¹ See page 129 *et seq.*

BIBLIOGRAPHY

- J. L. MYRES : *The Dawn of History* (Williams and Norgate).
D. G. HOGARTH : *The Ancient East* (Williams and Norgate)
ARCHIBALD LITTLE : *The Far East* (Clarendon Press).
J. FAIRGRIEVE : *Geography and World Power* (University of London Press).
M. I. NEWBIGIN : *The Mediterranean Lands* (Christophers).

CHAPTER VI

IRRIGATION EMPIRES OF THE ANCIENT WEST

IN the second chapter some mention was made of the irrigation remains which occur in the arid west of North America, and which refer to a people of whose social evolution and history very little is known to-day. On account of the character of their dwellings these aborigines are sometimes called the 'Pueblo People.'¹

These dwellings were large buildings of sun-dried clay (*adobe*) formed into bricks, though stones, often roughly dressed, were also used in their construction. A pueblo frequently occupied several acres of ground, and was from one to six or seven stories high; it might therefore be regarded as an immense tenement house or communal residence, holding a sufficient number of individuals to warrant the Spanish name of 'people.'

As in the case of the ancient agricultural communities in the East, the 'pueblo' may have been a tribal or irrigation unit, inasmuch as the gigantic aqueducts give evidence of co-operative labour on a great scale, and each pueblo may have owned the land supplied by the ditches drawing water from one of these great sources.

Among the native peoples and their descendants evidence is not lacking concerning the superior development of the inhabitants of the more highly watered districts. The Hopis Indians, for example, were apparently of the same race as the Utes (of Utah), but the first named ranked among

¹ It is significant that in Spanish the word 'pueblo' means both 'people' and a conversation or 'pow-wow'!

the most advanced of the Pueblo people, whereas the latter belonged to the lowest tribes of the tent-dwelling Indians. The districts inhabited by both receive the same amount of rainfall in the course of the year (16 inches), but the Utes could not raise crops for lack of water in summer; the Hopis, on the contrary, had sufficient summer rains (6-8 inches) at the time of high temperature to grow maize (Indian corn), beans, and pumpkins. They still continue their ancient practice of entombing a seed in a ball of clay, and burying the whole in dry sand. So treated, each seed is said literally to bring forth without difficulty its hundred-fold!

South of the Great River (Rio Grande) is a lofty plateau bounded east and west by the still more lofty escarpments of the Sierras Madre. These ranges are truly 'mother,' since the tremendous wreckage they have undergone through the operations of weathering has combined with the vast accumulation of volcanic outpourings to build up a tableland whose greatest length and width have been estimated at 800 and 500 miles respectively. This tableland slopes from a height above sea level of 8000 feet in the south to about 4000 feet in the north, and is intersected with still higher ranges, the ultimate peaks of those 'lost mountains' whose bases, once clothed with vegetation, are buried at enormous depths below. The winds, blowing in from either of the oceans, lose much of their moisture as they climb the surrounding heights, but the snow and rain of the Sierras in the appropriate season supply the sources of rivers which carry the water into the heart of the plateau. One consequence of this inland drainage and the surface configuration is the number of swamps and lakes that lie in the centre of the different 'hydrographic entities'¹ that carve the plateau into natural units for population.

The human history of this unique region is similar in many respects to that of ancient and agricultural Egypt.

¹ C. R. Enock (*Mexico*).

In those dim ages of which we have but the slightest knowledge it was the home of mysterious peoples erecting pyramidal earth-mounds, tombs, and temples, growing maize for food and maguey (a kind of agave) for drink. Sometimes one tribe and sometimes another held supreme power upon the Plateau, and more than once immigrants came in 'by way of the North.'

Most renowned among these immigrants perhaps because latest in time were the Texcocans and the Aztecs. As they furnish examples of empires based upon irrigation a few words concerning their history and customs may not be out of place. The Texcocans arrived in the twelfth century, and established themselves as a 'nation' of artists, poets, and historians, whilst their chieftains, with their baths, hanging gardens, harems, villas, temples, and cedar groves, recall in many respects the splendours of the Orient. Two centuries later saw the advent of the Aztecs. About the year 1325 these new invaders of the great Plateau-Valley reached a lake whose blue waters were sparkling in the sunlight. It is said that their attention was immediately caught by the sight of a magnificent eagle which, with wings outstretched, was perched upon the stem of a giant cactus. Accepting this auspicious omen they chose this sunny valley 'amid the waters' as the locality for their seat of coming empire, and forthwith drove the first stakes into the ground upon which the Imperial City of Tenochtitlan was later to be raised.¹

Here was a land of great natural fertility and one possessing means for a careful and industrious nation to supply by irrigation that water which was indeed otherwise lacking, but whose absence makes for cloudless skies and a splendid maturity of plant growth. Advance in civilization went hand in hand with advance in agriculture, and its influence upon the national life is displayed by the manner in which

¹ The native names for the capital of Mexico and the country were Anahuac (amid the waters) and Tenochtitlan.

agriculture was interwoven with civil and religious institutions. The deities associated with the operations of husbandry, the divisions of the year recalling seedtime and harvest, the payment of the public taxes in agricultural produce, all attest the esteem in which it was held. To this should be added the principles of land allotment, whereby there was an equable distribution among the cultivators so that all might work and none might starve.

This agricultural Empire of the Dwellers on the Plateau had reached the zenith of its glory under Montezuma I (1436-64), and the conquest had extended down the Sierra slopes to the waters of the Gulf. The business of governing was carried out by a code of laws which call for the admiration of all who read them. The kings were elected from among the brothers or nephews of the deceased monarch, this custom at once avoiding the possible intrigues of a long minority and permitting choice to be made of the prince who had shown himself best fitted to rule. Murder, even of a slave, was punished with death; and heavy penalties were meted out to a guardian who betrayed his trust. Marriage was a solemn contract and divorce could only be obtained after a careful judicial enquiry. On the lighter side of the national life were such arts as paper-making, picture and hieroglyphic writing, and the usual crafts of all civilized communities; nor was there lacking a taste for philosophical speculations of a kind that led the prince of the Texcocans to compose his prayers to 'the Unknown God.' Leaving out of count the religious ceremonies with their amazing number of human sacrifices, the setting of this great Empire was worthy of what, but for the heavy hand of Spain, might have been its destiny. Its cities with their strange, beautiful buildings, white and a-glow in the sun: the 'still' waters of the irrigation canals, winding through fields of yellow corn; the vivid green of the plantations and the dark forests of pine and cypress with their fragrant shade compare in several essentials with an equally splendid

civilization of the East that later went down before an invading power.

In other ways, too, the parallel still holds : in both were the same upkeep of military glory, the same benevolent despotism of an autocratic ruler, the same kingly palaces with their thrones of gold and gems. And the comparison can be carried still further to those scenes similar in tragedy if not in actual episode which closed the life of Montezuma II, the last Emperor of the Aztecs, and of Shah Jehan, the last of the great Moguls.

South of the Equator (actually from 2° North to 37° South) there lies another tract of highly elevated country. It is of wider latitudinal extent than is the Plateau of Mexico, and here, also at the time of the Spanish Conquests in the New World, flourished an Empire of a still more advanced type. How great an effort and how great a conception was involved in its building can be best understood by a study of the environment with which the Empire-builders had to deal.

Its territory extended, terrace upon terrace, from a narrow coastal plain, white and thirsty in the dry, tropical heat, to elevated slopes clad with an Alpine pasture above which towered stupendous peaks mantled in eternal snows. Its capital city was built at an altitude of over 11,000 feet.

The ranges of the Andes make a mighty wall for the plain below. They extend from north to south of the continent in single or duplicated folds, more or less parallel to the western coast. At places these ranges make loops around a lofty tableland, carving the country into intricate basins upon whose surface volcanoes rear their lonely heads. This region contains the highest elevations found upon the American Continents.

The small advantages the country had to offer for the establishment of a great State are vividly described by Prescott in his *Conquest of Peru*. "The sandy strip along the coast, where rain rarely falls, is fed only by a few scanty

streams that furnish a remarkable contrast to the vast volumes of water which roll down the eastern sides of the Cordilleras into the Atlantic. The precipitous steps of the sierra, with its splintered sides of porphyry and granite, and its higher regions wrapped in snows that never melt under the fierce sun of the equator, unless it be from the desolating action of its own volcanic fires, might seem equally unpropitious to the labours of the husbandman. And all communications between the parts of the long-extended territory might be thought to be precluded by the savage character of the region, broken up by precipices, furious torrents, and impassable *quebradas*—those hideous rents in the mountain chain, whose depths the eye of the terrified traveller, as he winds along his aerial pathway, vainly endeavours to fathom.”

The story of the peoples successively inhabiting the plateau is similar in many ways to that already slightly outlined in the foregoing pages upon Mexico. Repetition would be useless, especially in the face of our real ignorance of details. In this place it will be sufficient to call attention to the ruins of massive stone structures still to be seen upon the shores of Lake Titicaca and elsewhere among the highlands of Bolivia and Peru. These remains are admittedly the work of a very ancient race whose history is otherwise completely lost, but their character points to a well-developed native population far in advance of what is known concerning other Indian tribes of similar antiquity.

The unique isolation of this territory made foreign commerce practically impossible. Consequently wealth had to be sought by the only means through which true wealth under such circumstances can be obtained. It has been said¹ that gold and silver and the precious stones are not wealth in themselves. By convention they have come to be regarded as such, because of their exchange or purchasing power. In following this principle down to its roots it is clear that

¹ *Geography and World Power* (James Fairgrieve).

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the real wealth of a nation consists in the ability to procure, without too excessive hardship, sufficient quantities of the prime necessities of life under conditions which permit the cultivation of the arts and crafts and leisure from the serious business of food-getting, in order to study and enjoy them. It was upon these fundamentals that the wealth of the Inca Empire was based.

The difficulties arising from the surface features have already been touched upon. Here were no level regions extending for hundreds of miles along a mighty stream as in Egypt and Mesopotamia, nor was there any possibility of soil enrichment by periodically recurring floods. On the contrary, what was done had to be accomplished by marvellous engineering feats, and this by a nation living still in its Stone Age, and to which the use of iron was unknown.

The usual apparatus of irrigation in vogue in more favoured lands were here augmented. Extensive cisterns were carved out of solid rock; mountain torrents were embanked with thick courses of masonry; mountain slopes were terraced and sometimes even 'earthed' to very great heights. More land was claimed for cultivation by digging great pits through the dry soil to an underlying stratum, where some natural moisture was to be found; here after treatment with fish manure various kinds of grain and vegetables were grown. The islands of the coast also supplied a guano which was utilized as a manure. Where the soil was not otherwise infertile the arid coastlands were equally under cultivation. Canals and subterranean aqueducts, formed of freestone slabs accurately fitted together, brought the vivifying liquid from far distant sources among the mountains, and in one case, indeed, over a distance of at least 400 to 500 miles.

As the climate of this region is largely a function of the elevation, all kinds of crops were obtained, ranging from the luxuriant and easy growths of the tropical lowlands to the

cereals and grasslands of the temperate and cool temperate steppes, while the irrigated desert was made to yield whatever was most appropriate to it. Thus upon the lofty plateaus an industrious agrarian population cultivated fields of potatoes and maize, maguey and tobacco—this latter only for medicinal use as snuff—and on the higher slopes Peruvian shepherds tended flocks of llamas, the native sheep. On the lower Pacific terraces grew the cassava and banana trees, and other nutritious fruits that could be harvested for food. It is said that not an inch of cultivable ground was left waste.

In the Inca Empire famine was practically unknown; for a certain proportion of what was raised each year was set aside to provide against such a contingency. The soil was cultivated by the peasant class, which received in sufficient quantity, and when it was needed, grain, wool, and cotton from the government stores. There was a system of rotation of labour so that everyone might have leisure to attend to his own affairs, and each peasant household had enough land to enable it, with the above-mentioned government aid, to provide for its own necessities. One-third of the grain, cotton, and wool produced was set aside for the 'Sun,' that is, for the upkeep of the priesthood and everything pertaining to the national religion. The stores of the 'Sun' might be called upon in case of dire need for the peoples' use. A second third went to the Inca and the nobility, who were in most part the relations of the Inca or the descendants of Incas. They were feudal lords and formed the major portion of the military caste. As we have seen, the rest of the produce was held in trust for the people. At Cuzco, the capital, the quality of the grain and cloth was tested, so that the standard was kept up. Water allotment was in the hands of a body of officials whose duty it was to see that the precious fluid was put to its proper use. Clearly 'efficiency' was the key-note of the business of state.

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For the conduct of such an Empire means of communication were of the first importance, and in effect the great cities were linked together by splendid highways. One of them, about 1600 miles in length, ran from Quito on the equator to Chile. This was the Royal Road through Cuzco. It tunnelled through leagues of living rock; it crossed almost impassable ravines upon piles of solid masonry; it hung suspended above river gorges on bridges constructed of cables of maguey-rope, thick as a man's body. The greater part of its length was flagged with freestone, quarried in huge blocks which had to be brought from immense distances. When it is remembered that tools other than stone were unknown to these people, it must be conceded that the patience and ingenuity of the workers were truly marvellous.

Such is a brief account of the Ancient Empires of the West. Obviously they possessed many features in common, but here as elsewhere when circumstances could be utilized or turned, the more difficult country developed the higher civilization. In their last, and what for lack of evidence must be taken as their greatest phases, the two Plateau Empires of the New World were more or less contemporaneous; their destruction was primarily due to the same cause—the *auri sacra fames*—the lust of the Spaniards for gold.

BIBLIOGRAPHY

- ELLSWORTH HUNTINGTON, ETC.: *The Evolution of the Earth and its Inhabitants* (Oxford University Press).
- W. H. HOLMES: *Aboriginal Antiquities* (Smithsonian Institution, Washington).
- WILLIAM PRESCOTT: *The Conquest of Mexico* (Dent: Everyman).
- WILLIAM PRESCOTT: *The Conquest of Peru* (Dent: Everyman).
- O. R. ENOCK: *Mexico* (Fisher Unwin).
- O. R. ENOCK: *Peru* (Fisher Unwin).

PART III

MODERN IRRIGATION: THE OLD WORLD

CHAPTER VII

EUROPE

EUROPE received her irrigation system from Arabia through the Saracens, who entered the Iberian Peninsula at Gibraltar (Gibel-al-Tarik, or Rock of Tarik), the nearest point to the African coast. By A.D. 732 they had penetrated as far north as Tours, but the battle fought there marked the northern limit of their occupation. Their final expulsion from the Peninsula did not take place until 1492, seven centuries later. Between these dates the Moors, as the Saracen occupiers of Spain came to be called, succeeded for all time in stamping their agricultural methods upon that country, which by virtue of its configuration and climate closely resembled not only their African, but also their earlier north Arabian home.

Modern geographers place most of Spain, Italy, the Balkans, Asia Minor, Syria, and the coast lands of northern Africa—excepting where the semi-desert pushes through to the sea border—into one natural region of vegetation, that of ‘evergreen trees and shrubs,’ and into one climatic zone, designated the ‘Mediterranean Type.’ In this region the rain occurs in winter, the hot summer representing a period of total or partial drought. Rain during the cooler part of the year, when the surface evaporation is not great, provides the subsoil with moisture which, however, needs to be carefully husbanded in summer. It is the business of the plants of this region to adapt themselves to these conditions.

In the temperate broad-leaved forests rain is fairly abundant during the whole year, but the winter frosts may

freeze both the water in the soil and the juices in the plant, thus preventing the passage of the one—with its load of dissolved minerals or plant food—into and through the other. This process is called ‘checking absorption.’ Its work accomplished, through the agency of its leaves the plant restores to the atmosphere in the form of vapour such water as it does not need. This process is called ‘transpiration.’

Continual transpiration at a period when no water is entering the plant would injure it, so that the plants in this zone of vegetation have now conquered this difficulty as in the case of the deciduous trees, oak, beech, maple, elm, hickory, etc., by shedding their leaves in winter, or, as in the case of annuals, they spend that season in the form of seed.

North of the broad-leaved forests (or at higher altitudes) lie the coniferous forests, where the cold season is too long to be taken as a period of rest, and where warmer intervals at the beginning and end of each season must be utilized, there being, generally, no time for the transitional period when the leaves might be in bud. The trees have adapted themselves to these conditions by retaining the leaves in winter, but transpiration is reduced by virtue of their shape, which takes the form of ‘needles’ and other adaptations.

The Mediterranean Region is one of evergreen trees and shrubs, but evergreen for a reason precisely opposite to that existing in the case of the evergreen conifers. Here the winter, rainy and mild, is not generally a resting season, and on this account it would be unnecessary for the trees to shed their leaves. On the other hand, transpiration must be checked in summer at the time of the hot drought, and to this end the leaves of those ‘evergreens’ have undergone certain modifications, tending to be small and often spiny. Further, the subsoil, soaked and saturated in winter, holds much underground water in summer, hence the trees have long-spreading roots, enabling them to adventure far in search of this precious

material. The 'forests' are therefore open, indeed often very open, each tree requiring considerable space.

This region, one of summer drought, is also one of clear, summer skies, whence in the daytime the sun, untempered by the clouds of our northern lands, beats down upon the vegetation. To protect themselves against this fierce blaze the leaves of many plants are not only small but tough-skinned, leathery, and often intensely 'fleshy' owing to the presence of a stratum of moisture between almost infinitesimal layers of skin. The prevailing tone of the vegetation, attuned to resist the injurious actinic rays of the sun, is of a sombre grey. Such are the holm oak, olive, myrtle, oleander, and to this list may be added the holly, with us an emblem of Christmas, that is to say, of winter snow, but none the less a plant originating in this 'Mediterranean Region,' its small tough leaf, often more or less rolled into a thorn or prickle, being in truth a consequence of a habitat involving 'summer drought' rather than winter's frost. A grove of olives, with its scattered trees and their characteristically small leaves, hardly shades the traveller from the rays of the sun, and it is a detail not without its significant interest that the simile of a great rock giving shade to a weary land refers to territory containing the Mount of Olives.

The splendour of the fruit trees in this region—vines, oranges, lemons, figs, peaches, apricots, pomegranates—is no less a consequence of this summer drought operating through the medium of long-continued and powerful sunshine. Here peaches and pears grow almost untended on the hill-sides; grass there is none, or, practically none, its place being taken by flowering shrubs and small bushes, lavender, thyme, sage, etc., plants capable of withstanding not only the assault of the summer drought but the summer sun, by virtue of certain essential or aromatic oils which, being close to the surface of the leaves, protect their interior from the more powerful rays.

Some of the plants have bulbous roots with sufficient water stored up from the time of the 'former' and 'latter' rains (October–November; and March, April, or May, according to locality) to last through summer; examples are the onion and garlic, natives of this climatic zone.

On the other hand, the irrigated crops, for which to-day the region is so specifically noted, are not indigenous. Thus oranges, lemons, and the citrus family generally, appear to have 'originated' in the monsoon, and therefore well watered, lands of China and the East Indies. Sugar-cane and rice, now a feature of Mediterranean cultivation, were introduced by the Arabs from the tropical and subtropical countries of the Orient. It is noteworthy that there the chief rains generally come in the hot period, and it is this factor that necessitates irrigation when plants are introduced into a 'summer drought' area from these eastern countries. At the same time such introduction enhances the possibility of reaching a splendid maturity under the influence of the summer's cloudless skies.

It is generally supposed that irrigated agriculture in Europe was introduced by the Arabs, but there appears to be some evidence of an earlier 'organization of water.'¹ It is alluded to by Plato² and in certain Greek treaties and conventions. But it was for the Arabs to improve these small beginnings into a science, and hence in Europe irrigation is chiefly undertaken in Spain, southern France, and Italy, all 'Mediterranean' lands; and of these by historical accident and geographical position the first-named country should receive the first consideration.

SPAIN

The best known irrigated areas of Spain are to be found along the Mediterranean Margin and in the Ebro Valley. The winter rains of the highland rim are sufficient to feed

¹ Vidal de la Blache (*Principes de Géographie Humaine*, p. 94).

² 'Laws,' VIII. Quoted by Vidal de la Blache (op. cit., p. 94).

rivers which in their earlier courses run in deep, cañon-like beds, while the slopes, often entirely devoid of vegetation, have no means of retaining the moisture. The rain-storms therefore, violent though they may be, only give rise to temporary torrents after which the beds again run dry, or nearly so.

Many of these rivers, however, must pause before reaching the sea, for between the serrated edge of the plateau and the sandy stretches of the coast lies a crescent of lowlands, part of the still emerging continental shelf. Here are situated the famous 'huertas' or irrigated lands.

The prolonged period of high temperature allows valuable crops to be grown in quick succession wherever water can be obtained. The Romans practised some irrigation in this country, but it is to the Moors (the name in general use for the Arabs of this region) that the greater part of Spanish irrigation must be referred, and they brought with them from the Saracen gardens of the Arabian terraces all the skill and agricultural industry for which they were so famous. This included not only the terrace and huerta gardening, but the introduction of the sweet orange, sugar-cane, cotton, and the silk mulberry into a country where it is said that "the peasant still wears the silk sash and velvet jacket, and still follows the custom which he gave to the world—that of crowning his bride with orange blossom."¹

The summer temperature allows the growth of more valuable products than the winter rains, and this accounts for the 'new crops' of Arab culture, and the methods of irrigation and the water-rights in force to-day have undergone no essential change since the Moors were finally driven out of the country in 1492.

The peculiar customs or privileges connected with the process of artificial watering and water-rights in Spain vary

¹ L. W. Lyde (*Man in Many Lands*, p. 171). This gay attire may be worn on fête days, but in general male clothing is decidedly sombre. The silk industry too has greatly declined.

considerably in different localities, in consequence of the jubilation or compensation considered necessary at the time of the great 'Expulsion'; it will therefore be convenient to deal with such districts separately.

Granada

The city of Granada is famous for its palace of the Alhambra, built by Mohammed al-Hamar. In the present connection its feature of interest is the bell he caused to be placed on the highest tower of the building and which was struck every five minutes from sunrise to sunset in such a way that the peasant, by counting the beats, could tell the hour, and so know when it was time for him to open or close his watercourse. This ancient custom is still in force.

On the expulsion of the Moors, the reigning monarchs Ferdinand and Isabella¹ determined that the canals should be kept in working order, even granting their estates and water-rights to such remnants of the Moorish population as would change their faith.

In 1521 some rules were laid down for the division of the water among the different land-owners. Charles V added to these rules and appointed an 'acequero,' or water-ward, to see that the main channels were kept free from sticks, leaves, and river-floods, and cleaned out thoroughly twice a year. Penalties of all kinds in the shape of fines and imprisonment were enforced for misuse, wasting, or defiling the waters. A sort of 'Domesday Book' was drawn up, giving the names and privileges of those entitled to use them (1538-75), and this forms the present irrigation code of Granada. The canals drawing the water from the river Genil and its tributaries were constructed between 1242 and 1275. Each season carries two crops, of which maize is generally the second, though the after-crop may be beans or other vegetables. The first crops in the rotation are two

¹ Isabella [Late Queen of Castile] and Ferdinand of Aragon united their thrones by marriage in 1469.

seasons of wheat, then barley or flax, wheat, beans, hemp, and then back to wheat. Maize generally forms an after-crop for wheat, and vegetables for hemp.

Valencia

In the Province of Valencia,¹ a striking example is obtained of the wonders worked by irrigation. Here the coastal plains are larger than those of Granada, and their too-sheltered position in the lee of the great plateau-mass of Spain, together with their climatic average of temperature, would lead one to expect something not far removed from a parched and untilled waste. The reality is quite otherwise. The Heurta of Valencia has been fittingly described as "unsurpassed for green fertility," and it is said that just as there is no other region in Spain where agriculture is so dependent upon water, so is there nowhere else in Europe where the existing streams have been so skilfully utilized for irrigation.

The province is watered by three considerable rivers: the Segura, Jucar, Turia (or Guadalaviar), and many smaller streams rising in the mountains flanking the plain. All of these rivers are utilized for irrigation, but the most extensive system is that belonging to the Turia.

The Turia canals were constructed by the Caliphs who ruled in Valencia between A.D. 911 and 976. In 1238 King Jayme I of Aragon drove the Moors out of the province, but he understood and appreciated their irrigation works, which he ordered to be kept up as of old. "For us and our successors," run the words of the royal proclamation, "we give and grant for ever to you all, and to each one of the inhabitants and settlers of the city and kingdom of Valencia . . . all and each one of the canals freely and unreservedly, large, middling, and small, with their waters, and branches, and conduits of water beside the waters of springs . . . of

¹ The *historic* Province, including the administrative 'provinces' of Castellon, Valencia, and Alicante.

which canals and springs you shall possess the water and conduits and water courses for ever, always, day and night. And so you may irrigate with them and take the water without any obligation, service, or tribute; and you shall take these waters as was established of old and was customary in the times of the Saracens.”¹

The Arab name for the Turia was Guadalaviar (or White River). The last 10 miles of its course lie through the beautiful huerta of Valencia, the most perfectly irrigated district in Spain. Numerous canals branch out alternately from the right and left bank of the river, all the weirs that feed them dating from the time of the Moors. From the dome of Valencia Cathedral the Moorish City can be seen stretching white and far, till it meets the green wall of the ‘huerta’ perfumed with the scent of acres upon acres of orange trees. These same orange trees afford rich food for a species of edible snail which is considered a great delicacy when served along with the rice grown in the swamped lands of the huertas.

In this favoured region there is no enforced rest for the agriculturist, as crop follows crop without intermission. Soil exhaustion is prevented by rotation and by manure—no village being without its ‘guano-merchant.’ Vine, olive, carob (algaroba, from Sp. algarobba), almond, fig, date palm, esparto grass, grow here without irrigation; wheat, barley, oats, rye, lucerne, maize, kidney beans, hemp, rice, mulberry, require this artificial aid. In one agricultural year two wheat crops and a maize crop can easily be obtained from the same piece of ground. Lucerne is sown upon low embankments about 9 feet wide, and separated by water courses; for the greater part of the year the crop is gathered monthly.

The rice fields are levelled and enclosed by low walls of mud. When they become too full of water it escapes through

¹ Decree of King Jayme I, 1239. (Quoted by Scott Moncrieff, *Irrigation in Southern Europe*).

notches in the walls to the lower 'fields.' Sometimes the rice is grown in a sort of little nursery, to be replanted later in the fields. Elsewhere it is sown in the place where it is to be harvested, and for this method of cultivation the ground needs an initial preparation somewhat as follows :—

The land is ploughed in January or February, during which operation it is often entirely under water. It is then turned over again and again until the seed is sown at the end of April. A water weed which comes up at the same time is killed by one or two dryings. After the flowering in July the fields are again dried and the crop is cut in September.

The rice sown on the Jucar Canal system is of the nursery variety. Here, in January, the ground is watered over the stubble of the previous year, ploughed when it begins to dry, re-watered and re-ploughed or dug up while still under water. In March the seed is sown in nursery beds and kept under water till the end of May, when it is planted out in fields, 4 to 6 inches of space intervening between the different plants.

Throughout the greater part of the Province of Valencia the water-rights go with the possession of the land, but this is not the case in Alicante, which was not included in the kingdom of Aragon when King Jayme uttered his famous decree. Farther south, but still in modern Valencia, is the huerta of Elche, which owes its existence to the great dam built by the Moors, who also planted the date palms of the huerta. These are still flourishing and irrigated weekly. The trees of this grove are supposed to possess peculiar properties ; the leaves, blessed by the priests, are carried in procession on Palm Sunday and afterwards hung over the doors of the houses to prevent injury by lightning !

In Elche the water belongs to those who possess rights in the barrage and not necessarily to the owners of the land. Every morning the Irrigation Officer sells in the public hall the right for a whole day's watering (twenty-four hours), beginning at six o'clock that same evening ; even fractions

of a day's watering can be purchased. The sale is in the hands of a committee presided over by the *alcade*, but in Murcia, where the system of buying water is much the same, the rights are in the hands of a large number of proprietors.

Aragon

Saragossa or Zaragoza, the chief town on the Ebro, is the centre of an irrigated district producing olives, vines, tobacco and cereals, but owing to the cold winters, not oranges nor lemons. The Imperial Canal, connecting the rivers Ebro and Douro, is of more consequence for irrigation than for navigation.

The Castiles

Extensive areas in the upper Douro and Tagus valleys have been brought under cultivation by this artificial means, producing wheat; the region round Valladolid known as the Campos of Palencia (Old Castile) is also the famous 'granary of Spain.' The southern boundary of Old Castile is the high mountain range of the Sierras de Guadarrama and Gredos; here the rainfall is heavy, supplying sufficient water to irrigate Toledo and the gardens of the Royal Palace at Aranjuez.

The great irrigation system of Spain possesses certain features of particular interest. It includes the use of artesian water mainly for the cultivation of garlic and onions. Another notable characteristic is the specialization of products. Thus the olive oil of Andalusia and Catalonia (Sevilla, Córdoba, Lerida, Tortosa) has an excellence all its own, though olives are cultivated and oil extracted in many other parts of the peninsula. The oranges of Sevilla, the raisins of Valencia, the almonds of Alicante, all enjoy their special and peculiar fame. The cork of Catalonia and Alemtejo,¹ the wine of Oporto² and Jerez (note the corruption of these

¹ ² In Portugal.

names into port and sherry), are other examples, though cork oak is grown and the vine is cultivated practically all over the country.

The Terrace and Huerta irrigation of Spain is extended to the very similar Mediterranean region of the Atlas Mountains, equally subjected to winter rains and summer drought, equally brought under cultivation by the ingenious and industrious Moors. Here too, the hill-sides are staired with terraces, carpeted with tender green or golden grain according to the season, and here too, irrigation canals, spreading in a silver maze across the coastal valley of the Tell, water a well-favoured agricultural district.

ITALY

Italian irrigation is mainly limited to the basin of the River Po. The soil of this region, built up of the alluvium brought down by the torrents that scour the sides of the Alps and Apennines alike, is excellent and of a great natural fertility. The medial river has carried the load of land débris seawards for so many centuries that to-day it flows during much of its course on a raised bed of its own creation. This makes navigation dangerous and the river is only used for irrigation.

There is no season actually without rain, but the chief fall is in autumn, and the value of the much lower summer supply is effectively diminished by the high temperature of the region, due to the accident of its position, for it is girded by great mountain walls which powerfully reflect into the Plain the heat they gather from the sun. Thus, at the summer season the country has a parched appearance, and irrigation is necessary for successful crop growing. The irrigated area of the Po Basin occupies about 5000 square miles and is at once the largest and most highly developed irrigated area in Europe. Its traditions go back to the Ancient Romans: in the Middle Ages the Republic of Lombardy

practised irrigation on a vast scale, thereby combining useful agriculture with the draining of their low-lying land. In our own times it has been said that this region excels in providing "material for the liberal education of an irrigation engineer," and among its canals the famous Cavour Canal, in Piedmont, ranks first. Completed in 1867, it was first contemplated in 1844, when Francesco Rossi of Vercelli showed the possibility of using the water of the River Po for irrigation purposes. Ten years later the Sardinian Government instituted inquiries as to the best means of carrying out such a project. The problem, however, was laid aside, owing to the paramount interest in the 'Italian Unity' movement under the leadership of the King of Sardinia, and the life and death struggle with Austria. On the establishment of Italian independence the project was renewed with English financial aid, and the canal, in working order by 1867, was named after Cavour, the King of Sardinia's great minister.

The Cavour Canal is fed in winter by the River Po, which receives a heavy increment at this season; and in summer by the flood waters of the Dora Baltea, which result from the melting of the ice of the Savoy Alps. Its construction laid a considerable tax upon the ingenuity of the engineers; carried over the Dora Baltea in an aqueduct, passing under the Elvo in a syphon, there are no less than 345 bridges or tunnels for water along the length of the canal, that is to say, more than six for every mile.

Another interesting feature of the irrigation is the use of water which comes to the surface at the foot of the hills as springs or *fontanili*. The marcite fields in which winter hay is grown are supplied from this source as the spring water at this season is warmer than that in the canals.

Wheat, maize, and meadow grass are the chief cultivated crops of the lowlands of the Basin, with rice in the river bottoms. As regards this last mentioned cereal the Provinces of Novara and Pavia in Piedmont and Lombardy respectively

are the most important both in acreage and total yield. Rice here reaches a high excellence owing to the heat of spring and autumn and the latitude.¹ Rice irrigation is generally continuous, on account of the peculiar needs of the plant, but irrigation for other crops is effected by a 'rotation' or 'ruota' of fifteen days.

On the undulating country above the lowland thousands of mulberry trees are grown in connection with the silk industry. Here, too, the high grade of the product is due to the climatic and irrigation facilities, for while the plant requires both heat and water, the eggs keep best in a dry heat.

The practical details of the irrigation vary in different parts of the region. The water may be distributed by gravity in the manner to be described later,² or the meadows may be totally inundated. In some cases the irrigated area is divided into districts, each with an overseer in charge of a staff of water-guards whose business it is to supervise the delivery of the water into the minor water courses.

In the district west of the River Sesia each November the parishes forward to the Irrigation Association the number of acres of each kind of crop that they propose to raise the following year, and if it is impossible to allot sufficient water they may have to substitute some crop such as wheat in place of rice which requires so much. In this particular district the Irrigation Association has taken over from the Government the control of all the irrigation lying between the left bank of the Po and the right bank of the Sesia.

FRANCE

Irrigation is naturally practised in those regions of France fringing the Mediterranean Sea which are subjected to 'summer drought.' We shall deal with the Departments of Vaucluse, Bouches-du-Rhône, and Pyrénées-Orientales.

¹ See page 39.

² See pages 81, 82.

Near the junction of the rivers Durance and Rhône and along the course of the latter the country is very flat and the soil alluvial, conditions excellently adapted for irrigation. The irrigated crops are meadow grass and lucerne, beans, and other vegetables. Since the district receives a certain amount of rain, fruits and vines can be grown without artificial watering, and wheat only requires it occasionally. The lucerne, cut monthly, gives five or six harvests a year. *Norias*, or water-wheels worked by a horse or mule, are features of the irrigation.

The history of the installation of irrigation in this region possesses a special interest. The canals drawing water from the River Durance date from 1171, when Raymond V, Count of Toulouse, granted the Bishop of Cavaillon the right to divert the Durance waters into a canal for the purpose of constructing corn-mills. Sixty-four years later the Bishop of that period parted with his privilege to the inhabitants of Cavaillon in order that the water so diverted might be employed for irrigation. In course of time, as the practice of artificial watering became more common, the canal was lengthened and made to feed an increasing number of distributaries. In 1626 the Pope's 'lieutenant' at Avignon forced the inhabitants of Cavaillon to allow the distributing channels to be carried through their lands to irrigate those beyond. In this manner a large and well organized irrigation system was established.

The Marseille Canal, begun in 1839 and opened eleven years later, provided not only for the irrigation of the surrounding country, but drinking water for the city. The methods of its application cast an interesting light upon the ideals of organization of the founders of the scheme. The Municipality of Marseille, the authority which subsidized the canal, sold the water to the irrigators in quantities and at periods which might be quite irrespective of their needs, since they were obliged to take it when and in such quantities as it was allotted. The water-guards or *cantonnier-arroseurs*,

were supplied with a Municipal Schedule, a species of timetable covering periods of seventeen days and allocating the hour and length of time during which the different distributing ditches were to be opened. Each irrigator received his allotment at prescribed intervals so arranged that his day and night waterings gave a total equal to his scheduled amount. The system of water allotment in Vaucluse was very similar.

The remaining region of 'Mediterranean' France to be considered is the Plain of Roussillon, in the Department of the Pyrénées-Orientales. The coastal margin is barren, for the soil contains much salt, and landward beyond the Plain is mountainous country in which the rivers that water it take their rise. The lower slopes of the hill country are planted with olives and vines, for which the rain is generally sufficient, but the Plain, with an irrigation system reputed to go back to the fifteenth century, resembles the huertas of Spain. Canals draw from the rivers Tech, Réart, Tet, and Agly, and *norias* are in use for lifting the water. There are also artesian wells, particularly useful in the hot season when the rivers may become dry.

The Moselle Valley in the Department of the Vosges strictly speaking does not come into the category of Mediterranean Lands, but since Mediterranean climatic influences make their way thither up that historic funnel known as the 'Rhône corridor,' a short account of the origin of its irrigation works may not be out of place. The system was initiated as long ago as 1827 by the two brothers Dutac. The River Moselle rises in the Vosges and brings down a load of fine, brown, and very fertile alluvium. The stream is exceedingly rapid, and in flood-time the riverine lands on either bank may be widely inundated with turgid, rushing water. The problem was to fertilize this land with a not too swiftly flowing flood, and to irrigate it from the main stream after the subsidence of the waters.

The impounding of the water a little below Épinal by

a rough dam composed of boulders afforded a reservoir suitable for the carrying out of the scheme. Still lower down the stream embankments were erected wherever necessary to prevent the full current from sweeping over the land which still, however, could be flooded. Here was the irrigated area, which received its water in accordance with the method to-day described as irrigation by gravity. A main canal was dug from the reservoir, and from this canal smaller branches distributed the water along prepared and level terraces and so into subsidiary channels excavated on a gentle slope. A drain collected it after usage, and took it to a lower level, where the irrigating process was repeated. The land is still cultivated by this method; the character of the irrigation makes manuring unnecessary, and the yield is two or three crops of meadow grass a year. A somewhat similar meadow-irrigation is practised in many other parts of France.

Before leaving this subject of irrigation in Southern Europe, a few words should be said concerning the possibilities existing in Portugal and Sicily for cultivation by this method.

The western division of the Iberian Peninsula has not the same demand for the intensive irrigation so necessary in Spain, but the dry summer season makes it advisable on some of the rich agricultural lowlands of Portugal, where wells are sunk and the water recovered by the use of the *norria*. The Sicily orange and lemon plantations clothe the lower slopes of the northern mountains, and the irrigation required is effected by water obtained from the limestone springs.

BIBLIOGRAPHY

- O. C. SCOTT MONCRIEFF: *Irrigation in Southern Europe* (E. & F. N. Spon).
J. BRUNNES: *L'Irrigation . . . dans la Péninsule Ibérique* (Naud, Paris).
J. A. BARRAL: *Les Irrigations dans le Département de Vaucluse . . . (and) des Bouches-du-Rhône* (Imprimerie nationale, Paris).

CHAPTER VIII

THE NORTHERN WASTES OF AFRICA

THE geographical controls resulting in so large a stretch of desert-land have already been touched upon.¹ Northerly winds blowing from Europe have small tendency to take up moisture as they cross the comparatively narrow Mediterranean, but as they push into warmer latitudes they become increasingly capable of holding more water-vapour. Condensation can only take place when the air is sufficiently cooled through having to mount a highland barrier. This is so in the case of the Atlas Mountains in the north-west, where considerable rain falls upon the windward or seaward side, leaving a much drier wind to pass on the journey farther south.

The Sahara, in the tract of the North-east Trades, may be regarded as a 'trade-wind' desert. The sand of the desert, derived from the wasting of the surface rocks through extremely long periods of time, only needs the touch of water to reveal its amazing fertility. That very lack of rain which is so largely responsible for the desert condition has preserved to it the mineral constituents of which plant life is avid.

Much of the Sahara is of plateau character, and is partly hemmed in by the Atlas Ranges, the Abyssinian Highlands, and the northern edge of the plateau that occupies Central Africa. The first of these elevated regions, though experiencing a dry summer, as befits its latitude, receives rain in winter. The second is subjected in late spring and early

¹ See page 13.

summer to the outpourings of the monsoon winds which, hot and moisture-laden, have come in from the Indian Ocean (see p. 44 n.). Their journey thither is due to the heating up of Africa at this period, so that sea winds are drawn towards and across the Somali Peninsula. The third of these regions is continually drenched by the equatorial rains.

A large proportion of this rain gravitates naturally down the inward slopes of the 'basin,' and on account of the porosity of the soil much of it is lost underground. As was explained in Chapter III this water may be covered by a non-porous rock such as clay, or merely by porous sand, whose underlayers will accordingly be saturated.

Thus the basin of the Sahara and even the outlying Libyan and Nubian Deserts possess a considerable amount of underground water which in certain cases may be brought by the inequalities of the buried floor sufficiently near the surface for the roots of palm trees to reach it. When this is the case a 'natural oasis,' or 'desert garden,' may result. With the exception of dates most of the crops of the existing oases are artificially irrigated by recovered water. The size of an oasis may vary from a few date palms round a lonely spring to one tenanted by thousands of trees.

Stupendous as is the extent of this desert of shifting sand, the Sahara has never been a barrier to the intercourse of races and nations. For many centuries well-recognized trade routes have crossed it in all directions where the presence of oases have provided for food and water. Some of these 'islands of fertility' are veritable towns; practically all the existing oases are inhabited,¹ and in some parts of the Great Waste the wells that supply them have been flowing between fifty and a hundred years. In this region the wealth of a man is often assessed by the number of wells that he controls.

When France took possession of the greater part of

¹ A tract of uninhabited oases lies in the south of the Libyan Desert.

Morocco and Algeria, French engineers continued the oasis-making process, but with improved and modern methods.¹ The result was to bring under cultivation much of the country between Biskra and Tougourt in the Algerian Sahara. The main crops, of course, are date palms, with cereals in their shade, and the Biskra dates are said to be superior to all others. To obtain the water wells are dug to depths varying from 100 to over 240 feet, according to the locality. The issuing water when controlled often becomes a permanent stream. A new plantation may be started by anyone, since the land is free, but there must always be a minimum distance defined by law between the new trees and those already planted.

When once the water has been provided the process of oasis-making is somewhat as follows. The sand is first dug away to within a short distance of the surface of the underground supply, and banked up in such a way as to give the 'gardens' some protection from the wind. The newly planted date palms extend their long roots to the wet layers of sand, and need no further attention in this respect. If other crops such as onions, water-melons, and henna, are to be grown in the shade of the palms, open wells are dug and water recovered from them in a goatskin bottle fixed to the end of a swinging beam. This apparatus is known as the *khotara*, and resembles the Egyptian *shaduf*. The lump of mud used in Egypt is here replaced by a boulder of rock,² or the beam may be weighted with wood at the free end. The water is taken to the crops, over which women and girls pour it directly from the bottle. Wheat and barley are not grown here, and what is required must be brought from the Tell. The dates raised are for the most part of first-class

¹ The sinking of artesian wells appears to have been originally suggested by General Desvaux: the first well was sunk in Tamerna in 1856.

² In this region boulders of siliceous material are found buried in the sand.

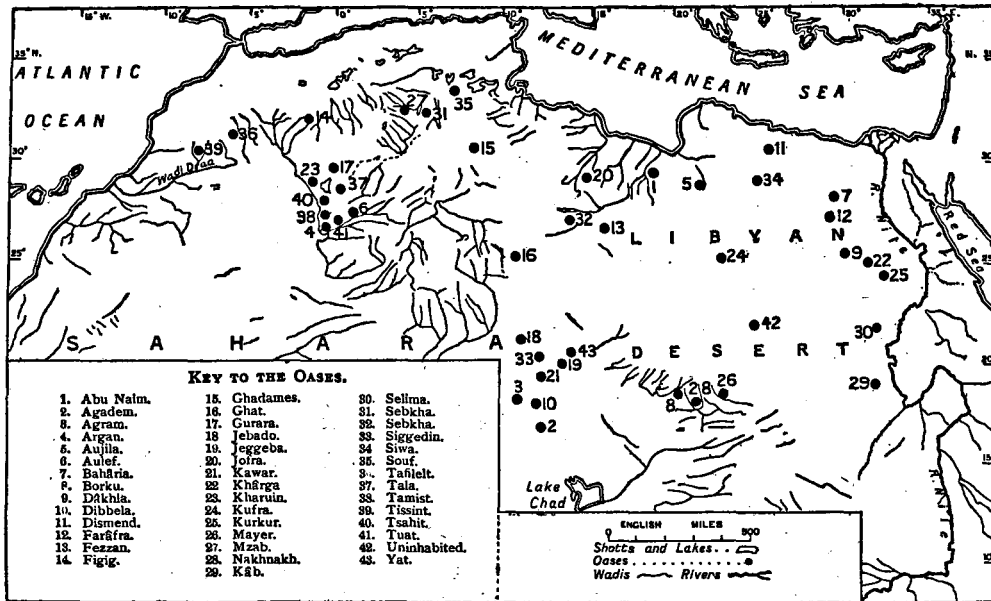
quality and furnish material for export. They are of the kind packed in boxes.

These oases must be continually and carefully watched ; there is always the tendency for the wind to drive back the excavated sand into its former position. In spite of the palm fence it blows into the ' garden ' and the cultivator laboriously collects it in baskets, carries it outside, and carefully deposits it on the summit of the unstable banks. This phase of the struggle with the desert is never-ending.

The oasis just described lies a little to the north-east of Tougourt, and is known as the Souf. To the south-west is the oasis of Mزاب, actually consisting of several small oases occupying a region of a very different character. Here sand-dunes, those reservoirs of water, are lacking, and in their place is stony desert intersected by the gullies of dried-up wadis. The western portion of Mزاب is the Sebkhah, whose configuration of tumbled, irregular, steep-sided ravines is due to its rock-material, a yellowish-white limestone, a species of karst.

The underground water is generally deep down where limestone and marl come into contact. Some labour may be avoided by digging for it in the beds of the wadis, but even so the wells may have to be sunk to a depth of nearly 180 feet. The water is not artesian, nor is it usually obtainable by the method of the *khotara*. It is drawn up in a sack attached to a rope passing over a pulley ; the lifting power is supplied by a man or animal walking down a prepared incline. It is then poured into a trough and led in little ditches to the irrigable area. These and the upper interior walls of the deep wells are carefully lined to prevent loss by leakage, local lime and gypsum furnishing excellent material for cement.

The wells in the Mزاب region have been said to number over three thousand three hundred. The water must be extracted from them without ceasing, because the soil by its nature requires so much. All day and all night, every day



THE NORTHERN WASTES OF AFRICA
 Diagrammatic Representation of the Chief Oases

and every night, can be heard the creaking of the rope against the pulley, and the incessant trickling of the constantly fed streams.

The great labour that must be expended upon the recovery of this underground water has naturally led to great care in its conservation and use. The Mzabite desires to get the utmost for his trouble, and the gardens of Mzab have the reputation for being more extensively and variously cultivated than elsewhere in this corner of the Sahara. Here, the 'blossoming desert' reveals a scene of singular loveliness—a maze of fig, pomegranate, apricot, and peach trees, bound together by the trailing sprays of the vine, the whole being canopied by the delicate fronds of the palms. Round the margin of each 'garden' beans and barley serve at once as a green fringe to this enclosed 'forest,' and a slightly more prosaic food for the industrious 'gardeners' of the desert.

The dates of Sebkhah are not profitable for export; their value consists in providing food for home consumption and a protecting shade for other growing crops.

In the south of Morocco is the oasis of Tafilet, famous for its vast and dense groves of date palms, and extending for more than 500 square miles. The fertility of the region is due partly to underground water and partly to streams rising in the Atlas Highlands. Water is drawn from these streams in a network of channels ranging in width from 1 to 30 feet, and in depth from a few inches to 6 feet. The large channels are well supplied even in the hottest season. The method of water distribution is of the simplest possible type, greatly assisted by the gentle slope of the country. The water is confined in ditches, slightly higher than the land to be irrigated, and when it is required a hole is cut in the side of the channel. When the soil has been sufficiently flooded the breach is stopped up and the bank again made solid.

An oasis of this magnitude necessarily contains villages and even towns. The chief harvest is, of course, the date,

which in the month of November engages the whole population.

An oasis in the desert south of Tunis has at least one feature of peculiar interest. It owes its existence to the flowing of an artesian well bored by Monsieur de Lesseps, the famous engineer of the Suez Canal. The water from the well rises 25 feet into the air; it irrigates from 400 to 500 acres of land, which is thus made to produce dates, pomegranates, tomatoes, onions, and cucumbers—the customary crops of the irrigated desert.

Upon the higher ground of the southern Sahara are situated the oases of Tibesti, Erdi, Borku, and Ennedi, explored for the first time by Europeans as late as 1912–17. Here grow 'corn' gardens intersected by parallel hedges, which shelter the ears of the grain from the violence of the north-east wind. The corn harvest is gathered in March, and then the ground is prepared for millet. The soil of this area is not very fertile, and the crops are correspondingly poor.

Further east extends the great Libyan Desert, with its strips of oases of unknown antiquity. The Dâkhla Oasis contains over four hundred wells belonging to the Roman or an even earlier period, and in addition about one hundred and sixty comparatively modern ones. They are very deep, being from 300 to 360 feet below the surface. The water lies in a bed of white sandstone underlying clay.

In this oasis there are some rather interesting methods of using and paying for the irrigating stream. As soon as a shaft has been bored and the first outrush of water has subsided, the amount of the normal flow is measured by a committee of government officials and the leading owners of the oasis for the purpose of determining what tax can be placed upon it. As the natives of Dâkhla are poor, each well is generally owned by more than one cultivator, and when a crop such as rice is grown the flow from the stream has to be divided between the owners of the water. This is effected by placing a board in the bed of the stream in such a position

that the water can only pass over its upper edge; this edge is cut into notches of equal depth, but varying in width according to the holdings of the individual owners. When the water has been apportioned in this manner, suitable runnels convey it to the cultivated plots. Obviously the assessment of the water tax will be based upon the width of the notches.¹ When the crops are other than rice, and in consequence only requiring a periodic watering, a system of six days' rotation is put into operation, and so arranged that all the owners of the water receive their just amount of day and night watering.

Another oasis in north-east Africa is that of Siwa, famous on several counts. Here stood the oracle temple of Ammon, and from a saline incrustation found in its neighbourhood, and consequently named Sal Ammoniac,² chemistry has been enriched with a new substance, and chemical nomenclature with a new term. The archæological remains and traditions connected with Siwa point to a habitation of the oasis for at least four thousand years. The presence of the Oracle drew pilgrimages to the locality in the days of the Egyptians, and among its famous visitors may be mentioned Alexander

¹ H. W. Hilton Simpson gives some interesting particulars regarding the irrigation system employed by the Shawiya of the Aurès Massif. He mentions a water-clock or 'clepsydra' which is used by these people for apportioning the water. The main channel is blocked with earth and a notch cut in the side of a branch channel (or *sagiya*) directs the water to a particular area. The assessment is made in terms of time as measured by the water-clock. A small bowl of copper or zinc, with a minute hole pierced in its floor, is floated upon water contained in a pail or earthenware jar. The bowl gradually fills and ultimately sinks, each sinking being recorded by the placing of a pebble on the ground. The cultivator is entitled to a flow of water estimated by the number of sinkings of the bowl. ("The Influence of its Geography upon the People of the Aurès Massif": *Geographical Journal*, Vol. LIX, No. I, January, 1922.) This word *sagiya* or canal is sometimes written *seggia*.

² Ammonium chloride, the sal ammoniac of commerce, was formerly imported almost exclusively from Egypt, where it was obtained by burning the dung of camels. The nature of this source of supply may throw some light upon the origin of the Siwa accretion.

the Great. To-day the oasis consists of scattered villages, and its outside trade is carried on with the Bedouin nomads—a barter of dates and olives in exchange for blankets, tea and sugar.

Though occupying the eastern section of the territory under review, the 'oasis' of Egypt possesses certain features which mark it off very distinctly from other irrigated areas in northern Africa. For this reason it will be considered in another chapter. Meanwhile it may be pointed out that the foregoing account by no means exhausts the number of 'spots of fertility' in the Saharan wastes, but they are sufficient to indicate the possibilities and products of desert cultivation and the variety of the means by which water for agriculture may be obtained. In addition, these brief descriptions may lead more forcibly than any mere statement of statistics to a realization of the true hydrographic nature of this unique country. As oasis after oasis becomes discovered or created, there gradually develops the idea of a vast underground 'land-surface' comparable in certain respects with the one with which we are familiar. The porous quality of the soil precludes evaporation of the heavy increment from the equatorial rains to the south. But whether the waters unite as a sand-choked sea, or whether they have carved separate beds into the underlying solid rock (there ramifying in great river systems such as the wadis would seem faintly to indicate) the result is the same: that there is here a tremendous natural reservoir yet to be utilized in ways and in quantities which, at present, man can only vaguely surmise.

BIBLIOGRAPHY

- C. W. FURLONG : *The Gateway to the Sahara* (Chapman & Hall).
 A. H. KEANE : *Africa*, Vol. I (Stanford).
 J. BRUNHES : *Human Geography* (Rand McNally, N.Y.).
 GEOGRAPHICAL JOURNAL : Vol. L, No. 5. Nov., 1917; Vol. LVI, No. 2. Aug., 1920; Vol. LVII, No. 1. Jan., 1921; Vol. LIX, No. 1. Jan., 1922.

CHAPTER IX

THE NILE

MENTION has already been made of the methods of irrigation in force during the time of the Ancient Egyptians. The pole-and-bucket sweep and basin irrigation are still features of the process. The novelty consists mainly in the scientific conservation of the water for regulation during flood, so that ever less and less escapes to the sea unused: and in the artificial raising of its height when the stream would be naturally low, thus facilitating and increasing the customary operations. The main British projects in Egypt are concerned with the details of this conservation.

The origin of the water and the cause of the seasonal flooding will now be considered.

The head waters of the Nile are on the very line of the equator, where there is rain at all seasons, though the amount varies; but since the main discharge is through Lake Victoria, the supply of the water at the source is fairly constant throughout the year. About 750 miles from its source the White Nile, under which name this part of the stream is known, meets a rather important tributary, the Bahr el-Ghazal, entering on the left bank, and contributing summer floods. Almost in the same latitude as the Ghazal is a tributary on the right bank, the Sobat, rising upon the Abyssinian Highlands, and consequently flooded by the spring and summer rains, though, owing to local circumstances, the maximum floods from this tributary do not enter the White Nile until

December, when they are partly spread over the lagoons and marshes that occupy this portion of the valley floor. Farther north the Blue Nile and the Atbara, also descending from the Abyssinian Highlands, are flooded from the middle of May to the middle of September, the waters of the one reaching a maximum about the beginning of this latter month and those of the other during the second week in August. The irrigation operations in Egypt, therefore, are mainly due to the Blue Nile and the Atbara, and the maximum high water is reached at Halfa, near the Second Cataract, about the beginning of September.

Owing to its greater speed, the Blue Nile ponds back the water of the White Nile and holds it up as a kind of lake, 280 miles in length, until a later month of the year when the floods are falling and its velocity is much reduced.

At Halfa, where the Nile enters Egypt proper, the river is lowest in the middle of June, after which it rises rapidly until September. During October and November it falls quickly, because the Blue Nile is falling, though the White Nile can now give a considerable reinforcement. From November onward the falling is accelerated and continues steadily until June. At Cairo the maximum flood occurs about one month later than at Halfa.

Below the confluence with the Atbara the Nile receives no regular stream, and on its passage through Egypt it loses greatly by evaporation, seepage, and withdrawal of water for irrigation by water-wheels, steam pumps, and arterial canals. In time of flood the river overflows its banks and 'naturally' fills all the basins and their connecting shallow ditches prepared for this emergency, and, on subsiding, leaves a covering of fertile silt which is not ready for planting until November. This allows for winter crops of wheat, barley, peas, lentils, beans, and onions. White clover is also grown for fodder and possesses the additional advantage of being a 'nitrogen-fixer,' thus preparing the ground for cotton.

In spite of this drenching of the land the flood waters were very largely lost as far as agricultural utility was concerned, and it is this surplus that British projects endeavour to conserve. For this purpose great barrages or dams built across the river convert stretches of it into mighty reservoirs, from which water can be run off at 'low' Nile, and so provide for the summer cultivation. The summer heat is responsible for the character of the crops, cotton, sugar, rice, millet, and maize being the premier agricultural products of Egypt.

The main or branching canals that take off the water from the dammed-up areas may have to be lined with concrete or cement to prevent leakage; on arrival at the irrigable district the water is conveyed to the 'fields' in ditches banked with earth. The removal and replacement of portions of the embankments diverts the water to the places where it is required.

Something should now be said regarding the individual schemes. The Emperor Napoleon was the first to suggest a scheme whereby the flood waters of the Nile might be more extensively utilized, but nothing was seriously accomplished until 1837. At this date Mohammed Ali ordered the construction of barrages and a canal, with the object of supplying water to the delta all the year round, and especially to provide for the growing of cotton, a summer crop, which he introduced into Egypt. A quarter of a million men were employed upon the construction works under conditions involving a 10 per cent. loss of life.

About 1870 the Egyptian Government employed French engineers to build two barrages across the Rosetta and Damietta distributaries of the delta, but after fifteen years of labour the enterprise was abandoned owing to the insecurity of the deltaic foundation.

The next attempt was in 1885, when Sir Colin Scott Moncrieff, already famous for his engineering work in India, undertook to complete the barrage at a cost of £500,000.

In this he was successful, the head of water being increased by 13 feet and in consequence over 2600 square miles of formerly useless land coming under cultivation.

Next, Mr. (afterwards Sir William) Willcocks drew up plans to hold back the main flood of water by erecting dams at Asyût, the capital of Upper Egypt, and at Aswân,¹ 350 miles further up the stream.

At Asyût the river narrows to half a mile in width, and in its neighbourhood was the Ibrâhîmiya Canal, already extending 200 miles. At Aswân the river rushes through a deep, granite gorge, a factor favourable to reservoir construction. Further, islands in the stream form natural piers upon which part of the great dam rests.

The Asyût Dam was completed in 1902, giving a rise of 12 feet above the usual level of the flood water; the Aswân Dam, completed in 1912, brought another 1500 square miles of desert under cultivation. In the latter case a further increase in the height of the barrage walls has taken place more recently.

The net result of the British irrigation works on the Nile is to render the once seasonal irrigation perennial. Formerly there were three divisions of the agricultural year: inundation, from the end of June to the end of October; crop-growing, from the end of October to the end of February; harvest, from the end of February to the end of June. The present system allows of two main divisions of the annual agriculture: winter crops, from October or November to April or May; and summer crops, from April to August in the areas of basin irrigation, and from April to October where the irrigation is of the perennial type. In certain localities there is a third and short autumn crop-growing season, when millet and maize are cultivated.

Notwithstanding the present satisfactory results of this enlargement of the agricultural harvest, disturbing factors have already begun to be manifest. For in the normal

¹ Spelt variously: Assouan, Assuan.

basin irrigation the ground at least obtained a considerable amount of fertilizing silt, which was made use of by 'winter' crops not as exhausting to the soil as, for example, cotton. To-day an appreciable proportion of this silt is dropped behind the walls of the Aswân reservoir. This means that there is bound to be an impoverishment of the soil sooner or later, especially when more than one crop is raised upon the same piece of land in a year. Artificial manuring is necessary and in operation in some districts, but in spite of this in the case of cotton there would seem to be a decline already. Though Egyptian cotton still ranks fourth in the world's production and third in the world's exports, it is now falling off both in quality and in quantity. There are, it is true, other factors involved in this decline, among which may be mentioned over-cropping, insect pests, and crossing of types.

There is another source of danger which always seems to accompany the modern scientific and thorough methods of irrigation. The soil in the Nile Valley is subject to water-logging, probably through seepage from the high level canals, and the saturation limit of underground water, or the water-table, is gradually rising. This means that the roots of the cotton plant, which require to be dry, may become too wet and so contract rotting disease.

The regulation of the Nilotic Barrage System is somewhat as follows. In November, when the level of the river is falling, and after all the soil to be cultivated by the flood has been thoroughly drenched, the sluice gates of Aswân are partially closed, and so remain through December and January. Behind the dam the valley is gradually filled. From April or May until August, that is during 'low' Nile, a canal draws directly upon this reservoir and delivers the water alternately to the district requiring it and to another reach of the canal. By the end of August the rise of the river permits unrestricted watering of the basins and perennially irrigated fields alike. A barrage at Asyût provides for high-level canals, which permit of perennial irrigation from



THE SENNAR DAM
Showing main canals, branch canals and distributaries.

here to the coast. An intermediate barrage at Esna makes it possible even in times of deficient flood for water to reach the higher ground near Wâdy Kena and Luxor, but in Nubia canals are infrequent, and the irrigation is carried on mainly by the *sakia* and *shaduf*.

The agricultural operations depending on the waters of the Nile have recently been greatly extended in the district south of Khartum, which is known as the Gezira Plain. The importance of the undertaking lies in the fact that the area offers great possibilities for the cultivation of the cotton plant, especially in view of the high quality of the fibre produced, which is in great demand among the manufacturers of Lancashire and elsewhere.

The peculiar facilities for irrigation of the Gezira Plain were pointed out by Sir William Garstin more than twenty-five years ago. This part of the Sudan lies in the fork of the Blue and the White Nile, and slopes more or less uniformly towards the latter river. It is therefore very suitable for the distribution of water by gravity, while the soil consists of a dense clay with underlying sand. An irrigation scheme was first seriously considered about 1911, and a beginning was made under the direction of Lord Kitchener, but the outbreak of war in 1914 put a stop to the work, which was not resumed until 1921.

The essential feature of the scheme is the storage dam at Makwar, near Sennar, which was constructed where an outcrop of rock in the bed of the Blue Nile supplied a suitable site for the necessary barrier. A main canal running parallel to the river's general direction carries the water from the reservoir so made upon a 70-miles journey before it reaches the irrigated region. Branch canals draw upon the main one and distributaries draw from the branches. Field channels or ditches take the water directly from the distributaries to the crops. The branch canals are structures of masonry provided with roadways, and escape channels return to the Blue Nile the surplus from the main canal.

The White Nile, flowing at a lower level than the irrigated district, eventually receives the water which the crops have not absorbed.

Much of the labour expended upon the construction works was entirely unskilled, but by July 16th, 1925, the project was sufficiently advanced to allow the main canal to draw from the reservoir and the official opening took place upon January 22nd in the following year.¹ At the present time about 500 square miles of territory are under cultivation,² but it would be possible to develop ten times this amount, and, in fact, a scheme for constructing a second dam higher up the river is already under consideration.

In the south-eastern part of the country there is in most years sufficient rain for the cultivation of *dhurra* (*sorghum vulgaris*), a cereal which is the staple food of the people of the Gezira. The cultivation of this plant has now been put upon a surer basis, and some nitrogenous crops may also be expected. The area, however, will be devoted chiefly to cotton, for which expert opinion anticipates a higher yield per acre here than anywhere else in the world. Labour for harvesting may be one of the problems of the future, but a certain amount of casual assistance is likely to be available from the Arabs of the Sahara and northern Nigeria, who pass through the Gezira Plain upon their pilgrimage to Mecca.

BIBLIOGRAPHY

THE OXFORD SURVEY OF THE BRITISH EMPIRE: *Africa* (Clarendon Press).

THE ENGINEER: August 28th, 1925.

GEOGRAPHICAL JOURNAL: Vol. LXVII, No. 3. March, 1926.

W. H. JOHNSON: *Cotton and its Production* (Macmillan).

¹ Lord Lloyd officially inaugurated the opening of the Sennar Dam on January 22nd, 1926.

² Statistics taken from *The Engineer*, August 28th, 1925.

CHAPTER X

THE ARID WEST OF ASIA

LONG ago Hāfiz, the great lyric poet of Persia, wrote the following lines in enthusiastic eulogy of his native land :¹

“Eden cannot show
A stream so clear as Rocnabad,
A bower so sweet as Mosellay.”

This paradise is to-day, however, an arid region of inland drainage whose interior plains and valleys display vast expanses of desert and scrub. It includes so much of Persia, Afghanistan, and Baluchistan as is known as ‘The Plateau of Iran,’ the Plain or Steppe Land of West Turkestan, together with that great peninsula which comprises Anatolia, Syria, Palestine, and Arabia.

Of the aridity of these regions there can be no doubt. Probably we are all familiar with the celebrated inquiry “What went ye out into the wilderness for to see?”—the wilderness, or desert, producing at its best only desert scrub or thorn, so that the Tempter might count with confidence upon the result of his proposal to transform miraculously its stones into bread. The phrase dealing with the desert ranger of Arabia, probably equally well known, is equally significant.

Yet through the hard brightness of these desert scenes there steals the faint aroma of lovely flowers and the fragrance of the vine. The rose of Sharon, the lily of the

¹ Translation from Hāfiz of Shiraz. (Poems of Parnassus Series.)

valley, were sung by the Great Syrian Chief as co-existent with the thorn forests. The famous lines of Omar Khayyám,

“some strip of herbage strown
That just divides the desert from the sown,”

epitomizes the whole of the arid table lands of Western Asia—a commingling of desert, semi-desert, and oasis, in part natural, in part artificial.

Much of Iran lies in Saharan latitudes, but in the mountainous west and north there is a winter precipitation. This rain and more especially snow provides for numerous streams which can be used in irrigation. Hot north-west winds blow into the interior basin from June to September, greatly hampering the successful cultivation of fruit trees.

On leaving the mountains the streams sink into the porous limestone, of which a great part of the Plateau is composed, and collect in underground channels which are called *kanats* and *karizes*. Some of these channels are natural while others have been constructed. As they get farther out into the plains they rise towards the surface and eventually become available for irrigation of the oasis type. From remote antiquity the inhabitants of both Persia and Afghanistan have been great practical irrigators, producing in particular, roses, opium, tobacco, all of which tend to soothe away the vexations of life and promote that Oriental philosophy which finds expression on the lips of their poets. Wheat, pistachio nuts, and grape vine, provided these philosophers with food and drink. The great reputation of Persian rugs and Persian silks reminds one of scented pastures and the luscious mulberry.

Where the *kanats* are numerous, towns have grown up. Among them may be mentioned Yezd, amid smiling groves of mulberries; Ispahan, with its wheat-fields and pasture land; Shiraz, whose very name harmonizes with the melodies set by its great poet to its roses and nightingales, so that to this day the maidens of Shiraz make an annual

pilgrimage to his tomb, carrying their bouquets of roses bound with brightly coloured silken handkerchiefs. Other oases produce date palms, but as the amount of water decreases thorn bushes and acacias are the chief forms of vegetation.

The region in which the three states of Persia, Afghanistan, and Baluchistan meet is known as the Seistan depression; though it contains the lowest part of the plateau, it is nevertheless about 2000 feet above sea level. Here the River Helmand pours out its last waters in what may once have been a lake but is now conveniently described as delta land. In the fourteenth century, the great Mogul chief Tamerlane¹ invaded this region and destroyed a large irrigation dam that crossed the river, and the country, once more productive than at present, has never recovered from the injury. An interesting feature of the irrigation system is the fact that canals are made to cross each other on bridges which are merely dried weeds pressed down into the water and covered with clay. As we should expect upon delta land, remembering Egypt, grain and melons grow luxuriantly; violent winds, however, limit the variety of the crops. It is significant that in the past Seistan had the reputation for being one of the granaries of Asia, but owing to the increasing desiccation² this reputation is not now deserved. Part of this inland delta, however, is too sandy for fertility even with irrigation, though the area does contain numerous villages supported by the River Helmand.

In Turan (West Turkestan) the river valleys provide an environment for a settled life based on agriculture. Wheat, maize, vine, cotton, tobacco, and mulberry are the customary products. The other inhabitants of this region are the nomadic dwellers of the steppe, between whom and the agriculturists there is little real sympathy or co-operation

¹ Or Timur.

² But see the note at the end of Chapter II. Similar causes might account for much of the apparent desiccation of Persia.

even though the 'nomadism' is not absolute; for these people winter in the lowlands and sow great fields of grain, leaving men to tend and irrigate them while the main population is away at the summer pasture-grounds. In due season these shepherds (the Kirghiz shepherds) return to reap their crops.

The Ferghana region of Western Turkestan is one of considerable agricultural wealth. Turbid streams and wind-blown sand have provided an exceptionally fertile soil, but cultivated areas must be protected by a growth of trees and shrubs. An additional danger is found in the rivers themselves, for they are torrential when in flood, and prone to overflow widely. This danger is avoided by the provision of canals which draw off the water. Cotton is a premier crop.

The chief city of Ferghana is Khokand, irrigated by the Syr Darya.¹ Tashkent, the capital of Turan, just westward of Ferghana, is irrigated by this same river but is not upon its banks. Other famous oasis-cities between the two Daryas are Bokhara and Samarkand, of whose former splendour in gold and gems the poet Hāfiz has sung. The one oasis is renowned for its leather and its Moslem piety; the other, a city of gardens, contains the most lofty citadel in Central Asia.

The greatness of Bokhara is likely to be eclipsed by Samarkand, for the River Zarafshan waters both, and the latter town, nearer the source, appears to be taking by far the greater share of the supply.

Upon the arid plateau of Asia Minor and at a height of 3249 feet above sea level, is perched the town of Konia, the ancient Iconium. Here the late sultan, Abdul Hamid, owned much land, and being more western in ideas than is customary with eastern potentates, he caused investigations to be set on foot as to the possibility

¹ The word Darya may have some common element with the Celtic derivatives for water. Other examples occur in the names of the Rivers Derwent, Durance, Dora Baltea.

of extensively irrigating certain localities. The execution of this project was finally entrusted to a German firm, and by the end of 1911 most of the irrigation plant was completed. The canal system is extensive, up to date, and western in principle, consisting of main, secondary, and tertiary canals, drawing water from the two chief rivers of the region and being supplied with masonry barrages and regulating sluices of a modern, scientific pattern. Its subsequent history, however, illustrates a well-known Biblical allegory. Emigrants from the Crimea, Caucasia, Rumelia, etc., were invited to exploit the irrigable area and were lured thither with promises of land, houses, and corn seed, promises which were speedily broken (1919), leaving destitute some two thousand families whom the government had imported.

The Arab system of cultivation, so well exploited in North-West Africa and Spain, originated, as has already been pointed out, in Arabia. Yemen, in the *jebel* or mountain land of the south-west, contains the ruins of extensive irrigation dams pointing to great agricultural operations in the past. It was, in fact, the 'Arabia Felix' of the Ancients. There are two rainy seasons which provide for torrential streams down the steep western slopes, and this and the configuration of the country may have suggested the system of terracing. At the present day this system is still in excellent working order. Primitive barrages control the streams, and the terraces which, tier upon tier, line the mountain slopes, must have been constructed at the cost of considerable labour.

In some districts they offer a lovely spectacle of perfumed flowers: roses, jasmine, lavender, thyme; in others, coffee shrubs, sheltered from the sun by fig and tamarind, and nightly drenched in the mists that rise from the warm sea below, gather that fragrance which has enabled the followers of Mohammed to make coffee their customary beverage in place of the juice of the vine.

The method of cultivating coffee recalls one in use for rice. Seedlings are allowed to grow in a 'nursery' for six weeks or so and are then planted out in rows about five feet apart. The shrubs are watered every two or three weeks.

The narrow coastal strip at the foot of the mountains is utilized wherever the torrents have built up patches of alluvial soil. Every little stream and rill is 'controlled.' The date palm, which flourishes upon the more sandy patches, furnishes here the chief article of food. Elsewhere is poor pasture or desert.

The province of Oman, in the south-east of the peninsula, appears to have been little known to the Ancients, and its present elaborate system of irrigation belongs to a much later time. It includes careful use of permanent springs, underground channels of the *kanat* type, and the establishment of palm groves, the dates of Oman being an export crop renowned for its excellence.

Farther north lies the large oasis of El Hasa, described as the most flourishing spot in all the Desert. Groves of date palms give shade for lucerne; pomegranates, apricots, citrons, rice, barley, onions, and sunflower seeds (for eating) are also cultivated. The water is derived from perennial springs, which are sometimes warm, and provides irrigation involving canals, masonry aqueducts and water-lifts of the kind used in the Mzab. A settled population of eighty thousand souls is reinforced in summer by nomad Bedouins who are attracted thither by the water.

The Biblical narrative gives some account of the traditional vegetation of Syria, to which one significant reference is found in the joy expressed by the Israelites upon attaining that promised land of Canaan "with milk and honey blessed," that is to say, a land of cattle and flowers, a steppe environment. But they also found the hillsides terraced for viti-culture and Canaan a land of corn and wine. To-day it is recognized that Palestine is specifically drier than it



Science & Art Museum

WOODEN WATER-WHEEL, HAMA, SYRIA

The water is lifted in pots attached to the rim. The wheel is driven by float boards on the rim which dip into the stream.

was at the time of the birth of Christ, but even then irrigation was necessary for successful and abundant production.¹ After centuries of neglect the once 'promised' land has at last been wrested from the devastating suzerainty of the pastoral Turks and it may be not too late, even now, to arrest those desiccating influences which their occupancy has accelerated. But Palestine cannot be saved by half measures and the whole resource of modern scientific irrigation methods may have to be employed. Meanwhile, since the War certain schemes have been suggested for utilizing the fresh water of the Lake of Galilee and the River Jordan. It has been proposed to put a barrage across the river and its tributary, the Yarmuk, and to draw off the water so stored by two canals to be constructed along the upper edge of the valley floor. It has been said that such a proceeding would permit restoration of the former intensive cultivation to the Jordan Valley and the Esdraelon Plain.

Of course irrigation on a small scale has never gone entirely out of use. At Hama, for example, on the River Orontes in northern Syria, there is a giant water-wheel reputed to be the largest in the world. It measures 70 feet in diameter: wooden buckets fitted on to its outer rim lift the water and deposit it in a stone aqueduct above, from which it is carried to the surrounding orchards and vineyards. Similar but smaller contrivances provide both for irrigation and town use. Apart from this, grain and the vine have always formed crops in Syria, the water of neighbouring brooks being turned aside to satisfy the thirsty soil.

The ancient route-city of Damascus, that 'paradise of the Arab world,' deserves a word to itself. It has long been renowned for its orchards of fig and apricot, its groves of walnut trees and rose-entangled vine which have made the gardens of Damascus the poet's fervid theme. Here the

¹ Is this the meaning of the "still waters" in Psalm xxiii. 1

Abana (Barada) drawing its life from the heights of Anti-Lebanon, divides into numerous distributaries and so dies out in the desert sands after having given birth to one of the most famous oases in the world.

BIBLIOGRAPHY

- D. G. HOGARTH : *The Penetration of Arabia* (Alston Rivers).
O. R. ENOCK : *The Tropics* (Grant Richards).
E. HUNTINGTON : *The Pulse of Asia* (Constable).
R. PUMPELLY AND E. HUNTINGTON, ETC. : *Exploration in Turkestan*
(Carnegie Institution, Washington).
SIR M. CONWAY : *Palestine and Morocco* (Arnold).
GEOGRAPHICAL JOURNAL : Vol. LIV, No. 5. Nov., 1919; Vol. LVI,
No. 6. Dec., 1920; Vol. LXIII, No. 3. March, 1924; Vol.
LXVIII, No. 6. Dec., 1926.

CHAPTER XI

LANDS OF LITTLE PROMISE

TO the east and north of the countries considered in the last chapter lies that central depression of Asia known as the Tarim Basin. Except in the Lob Nor area its floor is at an elevation of 3000-4000 feet and eastward it passes imperceptibly into the Plateau of Mongolia, with its rainless district of Gobi. Southward it is separated from the still higher Plateau of Tibet by the wall of the Kuen-lun ranges. These three regions, the Tarim Basin (sometimes called Eastern Turkestan), the Plateau of Mongolia, and Tibet are arid lands with certain features in common that enable them to be grouped together.

The Tarim Basin is cut off in every way from water-bearing winds, but the mountains that surround it on three sides are very lofty, and their winter snows abundantly feed the streams that enter it and provide for such fertility as there is. The story of the desert (sand), the strip of herbage (scrubland), and the sown land (represented by fertile alluvial flats) is here repeated. The river appears to have lost many of its former tributaries, which either do not now possess sufficient water to enable them to reach it or have to traverse tracts more sandy than of yore. The Tarim finally disappears in the reedy swamps of the Lob Nor. However, man has done his best with the water that is available, and along the edge of the basin, at the foot of the Thian-shan Mountains, there is a considerable number of oases both large and small, lying athwart an ancient caravan route¹ like beads upon a thread. Their permanency and their importance is due to the volume of the many rivers

¹ The Thian-shan-Nan-shan Road to Kansu, in China Proper.

descending the mountains, and to the configuration of the ground which is very advantageous for irrigation purposes. The chief of these oasis-towns are Yarkand and Kashgar, cities once famous for their Oriental magnificence. Their low, flat-topped houses are surrounded by gardens and fields in which wheat, rice, maize, mulberry, cotton, cloves, fruit and the vine adequately supply all man's real needs. The fine, fertile soil arises partly from the turbid irrigation streams in the flood season, and partly from the accumulation of wind-blown sand. The cultivated ground is slightly terraced and has to be protected from the winds by a wall of trees and small plants to prevent this covering silt from being blown away.

The Takla-Maken Desert separates this northern belt of oases from a second belt, situated at the foot of the Kuen-lun Ranges. Here the 'spots of fertility' are less numerous and more completely surrounded by true desert. Khotan, on alluvial and fertile soil, is fortunately supplied by two rivers, of whose irrigation possibilities the fullest use is made. Except for Khotan and Karghalik, all these oases are terminal, that is, they are not placed on the barren piedmont gravel, but out upon the finer soil of the desert some little distance beyond the point of final disappearance of their streams.

The Lob depression occupies a natural division of the Tarim Basin wherein no aspect of nature could appear more desolate. The waters of the Tarim are lost in salt marshes and beyond them lies a waste of salt, sometimes hummocked like waves, the whole representing the bed of a former lake. Mounds of gravel, sand, and clay, weathered by the wind into fantastic shapes, afford scenic diversity. The piedmont of the ranges to the south appears to have been at some time rather extensively cultivated, and it is on these long abandoned sites that the present population of about four hundred households has gathered. Here the waters of the many streams rising on the Kuen-lun spread

themselves out in numerous small channels before their final disappearance beneath the gravels of the basin floor. Banks of gravel thrown up on the spot dam back the water which is thus made to collect in a single large 'reservoir' for irrigation. It is then run off in shallow ditches dug in the gravel or loam of the flood plain, and used for raising wheat, maize, melons, and fodder for cattle and sheep. The salinity of the streams, however, occasionally tends to lessen production.

Whatever may be the causes which have resulted in the undoubted great aridity of the Tarim Basin, it is unlikely that as a home for man it ever has been or ever will be of much account. Huntington, with characteristic American optimism, supported by consideration of the reclamation carried out in the arid western deserts of his own country, has hopes. He points out that there must be much underground water which could be recovered and more effectively retained in concrete-lined canals and trenches, so that new oases might be created and old ones enlarged. This would necessitate a considerable outlay of capital which the present rulers of the country are unlikely to supply. But Huntington thinks outside interest might be tempted by the gold and metals of the mountains; whilst the fall of water, which is very great, could be made to produce power for manufacturing purposes, for which the products of the oases might contribute the raw material. The isolation of the district, however, must make these hopes for the present very illusory.

The Desert of Gobi or Shamo is less desolate than the Takla-Maken. For though 'Gobi' signifies 'great' and 'Shamo' signifies 'sand,' there is sufficient rain for a thin straggling herbage in early summer, supporting at this season a nomad population with its flocks and yourts (black tents). China is beginning to make use of Mongolia and the fringes of the desert wherever careful irrigation makes agriculture possible.

To the south of the Tarim is the cold, plateau land of lofty Tibet. Here, near the headwaters of the Indus and Brahmaputra, in the south-west corner of the country, there is sufficient summer heat for grain and fruit. But the nature of the bare, rocky surface is unfavourable to cultivation, and so when the slopes are not too steep a kind of shelf or terrace is laid out and covered to the needful depth with soil that has been brought laboriously from the lower valleys. A manure is supplied from the ashes of argol (the dried dung of the yak and other beasts, which has already played the part of household fuel in this necessitous land). Water is brought in channels along the hillsides from the distant snow-fed streams.

The resulting harvests provide food for the Lamaseries, or community dwellings of the priests, and with so pious an object in view, labour will not be lacking.

BIBLIOGRAPHY

- E. HUNTINGTON: *The Pulse of Asia* (Constable).
R. PUMPELLY, E. HUNTINGTON AND OTHERS: *Exploration in Turkestan* (Carnegie Institution, Washington).
SIR AUREL STEIN: *Innermost Asia* (*Geographical Journal*, Vol. LXV, Nos. 5 and 6).

CHAPTER XII

THE LAND OF THE TWO RIVERS

THE popular name for the Euphrates-Tigris Trough is Mesopotamia, signifying the 'land between the two rivers,' but in view of its deltaic formation the 'land of the two rivers' would be the more correct designation. The agricultural possibilities of this region depend uniquely upon the relation of climate and relief. The two mighty streams receive their headwaters from the highlands of Armenia, while the Tigris, in addition, is fed by many tributaries, originating on the Persian Scarp. Throughout the Trough the rainfall is typically Mediterranean, three-quarters of its annual amount occurring in winter as the 'former' and 'latter' rains, with light showers in between. These rains fall most heavily in March, and provide for some natural grass, a feature generally absent from such Mediterranean countries as Spain. Unfortunately, the distance from the sea results in a low precipitation—Bagdad, for example, having an annual total of ten inches.

From April onward, the temperature is very high, so that south-west winds effect a rapid melting of the snow on the Armenian and Persian heights. In consequence, the March-May floods are large, and bring down with them vast quantities of silt. The water is at its lowest in summer, when heat pours into the 'trough' from the burning sands of Arabia. Differences in temperature are very great, ranging through as much as 100° F., so that in spite of the summer heat, the nations growing up here have been virile and energetic.

The part played by the relief of the country has had its own peculiar influence upon irrigation problems. Mesopotamia contains no land above an altitude of 2000 feet; a line joining Aleppo and Mosul would coincide approximately with the 1000-foot contour, while south of Hit-Samarra (the one on the Euphrates, the other about a hundred miles north of Bagdad) practically all the country is less than 500 feet above sea-level. Mesopotamia, therefore, may be regarded as a gigantic lowland, with gradients of the slightest. The importance of this gentle slope to the south-east is that only a very fast river will carry its silt; this is the case with the Tigris, but the slower Euphrates begins to free itself of its load a little below the Aleppo-Mosul line. This deposition raises its bed to such a degree that when it is opposite Bagdad, it is 25 feet above the general level and water can easily be sent from it to the Tigris. In this way the intervening territory can be provided with excellent irrigation by gravity. Nearer the sea the Euphrates flows over a gulf filled in by Tigris mud, the latter river being now at the higher level: water can be sent, therefore, from this stream to the Euphrates, making a second easily irrigated area 'between the rivers.'¹

In addition to the gentle longitudinal slope, there is a remarkably steep transverse one which, however, hinders rather than helps in the irrigation operations. The rivers cannot carry the flood waters in their proper channels and in abnormal times, flowing as they do over raised beds, they break their banks but, owing to the shape of the valley, the spilt water cannot easily return to the main streams and floods may be disastrous.

We have seen how this land, previous to the Turkish occupation, was enabled to raise splendid agricultural Empires. Now much of it lies waste with broken and choked-up irrigation canals, and until 1914, it bid fair to return

¹ Near Samarra, where the bed of the Tigris is below the general level, water is lifted from the river by pumping and other methods.

to desert and steppe. However, it must be conceded that even before the War of 1914-18, the Turk (perhaps under German influence) was waking up to its possibilities. In 1909 the Turkish Government employed Sir William Willcocks to supervise reclamation works on the Euphrates, and by October, 1913, two dams constructed under his direction had restored the Hilleh branch canal, near the site of Babylon, which had been out of use for the previous fifty years. Equally important reclamations were projected elsewhere, but the outbreak of war caused them to be abandoned for the time being. More recently the immediate utility of the Willcocks' plans has been questioned and a modified programme is under consideration.

Some difficulties experienced in attempts to irrigate this region have already been touched upon,¹ but there are others. One of them that is not the least serious lies in the Arab propensity to remove water from the sides of the stream where the velocity is least. The result is to reduce the amount of available silt that can be deposited at the moment as a top dressing, and also by this 'overloading' to cause injurious bed-raising lower down the water course. Another trouble is caused by the silting that takes place at the mouth of the take-off canals. To prevent this and to keep up the steady supply of water into the side channels, the whole system requires to be carefully watched and kept free from obstructions.

The most important crop at the present day is the date—here indigenous. Mesopotamia accounts for about 80 per cent of the world's production and the Basra delta is the chief area for its cultivation. It provides the Arab with food, drink, and foreign commerce. Each year 80,000 tons of dates are exported from Basra. The fruit is inferior to the African variety and is not packed in the familiar date-box.

Along the Shatt-al-Arab, at the head of the Gulf, there is irrigation of an unique character. The rising tide drives

¹ See page 50.

back the waters of the distributaries and causes them to overflow their channels. In this manner the land is inundated twice a day and the date palm, which grows so nobly in the somewhat alkaline soil of the Sahara, has no objection to the brackish watering which it now receives. The tidal irrigation of the Shatt-al-Arab supports the largest area of Mesopotamian date cultivation.

Rice grows in the same localities as the date. The maximum cultivation is in the province of Iraq, a true 'Mesopotamia' a little to the north of Basra and in the Euphrates-Tigris fork. The yield is heavy and the Arabs growing it are the richest in the land.

Wheat and barley are 'temperate' crops, and grow best round Mosul, where the rainfall (10 inches) is generally sufficient; but irrigation is possible if required. At suitable seasons of the year they are also produced farther south, upon the raised river embankments, where they receive a short-flood irrigation which is over before the May harvest. The cereals are mainly used for home consumption, though owing to its high quality there is a considerable export of barley.

Cotton has long been grown in Mesopotamia, and was used locally for pillow-stuffing and clothing. It is only since the War that the country has been considered as cotton-producing, and under British encouragement in this respect may yet rank high.

The Eastern Irrigations, Ltd., and a subsidiary company, known as the Diala Cotton Plantations, Ltd., are among the latest and most extensive undertakings in connection with this product.

There are obvious lines upon which future development is to be expected. Not even in Babylonian days was full advantage taken of the possibilities of the area. The tributaries flowing from the Persian Scarp do so in gorges across which dams could be thrown and hence water stored to irrigate much land now steppe or actual desert. But this

would necessitate a complete revolution in the life of the inhabitants of that part of the country, the 'fighting' Kurds, and it is always difficult to get pastoral nomads to settle down to peaceful agriculture.

Regarding increased possibilities from the Two Rivers, it has been estimated that they are capable of irrigating 7,000,000 acres in winter and 3,000,000 acres in summer.¹ Full advantage could be made of them only if they ceased to be used as a means of transport, which might be equally well effected by the construction of light railways, and in any case is difficult for native boats going up-stream. This necessary change ought to be easy to carry out in view of the fact that a British company controls the transportation on the Euphrates-Tigris streams, and that British capital is invested in the railway, which already runs north from Basra to the neighbourhood of Mosul.²

On this reclaimed land the usual Mesopotamian products could be raised, with the addition of tobacco and silk, thereby greatly increasing the commercial importance of the region.

Thus though there are already some well-developed irrigation areas in Mesopotamia, perhaps as a whole the country still remains a land of promise rather than of fulfilment.

BIBLIOGRAPHY

- G. CHISHOLM : *Handbook of Commercial Geography* (Longmans).
 ISAAC BOWMAN : *The New World* (Harrap).
 PEACE HANDBOOK : *Turkey in Asia*.
 W. H. JOHNSON : *Cotton and its Production* (Macmillan).

¹ I. Bowman, *The New World* (1924).

² 1924.

CHAPTER XIII

MONSOON ASIA

INDIA

THE term 'Monsoon' is derived from an Arabic word signifying 'Season.' The countries known as the monsoon lands receive their rain in summer, or summer and autumn, while for the remainder of the year there is a very much smaller fall or even absolute drought.

For the better understanding of the cause, amount, and locality of the rainfall, or of the drought, rendering irrigation both possible and profitable, a short description of the Monsoon Wind phenomenon may be useful, and as in this connection India possesses certain characteristic features, we shall deal more particularly with that country.

In winter the January temperature in Bombay is about 74° F., but at Lahore in the Punjab it is only 53° F. Along with the lower temperature goes a relatively high pressure, from which winds flow outwards down the Ganges Valley, and veering round when they reach the Bay of Bengal, blow across the south of India from the north-east. This land is in the latitude of the north-east Trades, which in this quarter have accordingly become reinforced. As these winds are blowing towards the equator they are technically 'dry.' During the earlier part of the season there is some rain on the southern portion of the Coromandel Coast and eastern Ceylon, usually attributed, however, to the retreating south-west monsoon.

By April the mean temperature is over 80° F., and India is relatively a low pressure area. This weakens the north-east or dry monsoon, and winds begin to blow landward

from the Bay of Bengal and the Arabian Sea, depositing moisture especially where relief opposes a barrier over which the air must rise.

Towards the end of May, when the temperature of India is at its maximum, these latter winds are reinforced in their turn. The south-east Trades pass the equator as the sun approaches the northern tropic, and are deflected towards the west coast. By the first week in June this south-west monsoon, as the system is called, has reached the northern shores of the Arabian Sea. These winds have travelled over vast stretches of ocean and in warm latitudes, so that they carry an enormous quantity of water vapour. On reaching the coast they have to surmount the lofty barrier of the Western Ghats, a circumstance causing them to shed the greater bulk of their contained moisture on the seaward slope. They pass over the Deccan as winds of the *föhn* type, so that, though it may occasionally receive a few showers, this region is the famine zone of India. Some of this wind enters the country by way of the Thar Desert, and after crossing the Delhi Ridge it ascends the slopes of the Himalayas to their summit, shedding the last vestiges of its moisture to feed the sources of the great rivers.

Meanwhile a second current of air has entered the Bay of Bengal between Sumatra and Ceylon. Much of its force is spent in Burma and Assam, but though it is very considerably weakened by the time it reaches Calcutta, this wind is the source of the rains in the Ganges Valley. These rains are mainly cyclonic and fall independently of land relief,¹ but even with this precipitation the wind is still carrying water vapour. It eventually joins the monsoon that has crossed the Thar, and assists in feeding the lofty Manasarowar

¹ Rainfall "up" the Ganges Valley :—

Calcutta : Annual amount, 62·7 in. ; during monsoon, 50·8 in.

Fyzabad : Annual amount, 43·6 in. ; during monsoon, 40·2 in.

Delhi : Annual amount, 27·4 in. ; during monsoon, 23·5 in.

(*Geog. Jour.*, Vol. LXV, No. 2, Feb., 1925, p. 142).

Lakes, wherein the Indus takes its rise. The irrigating value of this river will be considered presently.

The heaviest rainfall occurs in June, July, and August, the period known as 'the rains.' In September the heat begins to wane and the monsoon, for it is to the summer system of winds that the name is generally given, begins to move southwards, giving place to the north-east Trade, or *dry* monsoon. By the middle of December this latter wind is again established over the whole of the Indian area.¹

An analysis of this short account of the régime of the winds brings out clearly several important points. The Deccan appears to receive but little moisture at any time: the Ganges Valley, with a 'winter' temperature sufficient for the growth of a variety of crops is in the region of 'summer' rain: the Himalayas, draining the monsoon of its last moisture, may store up in the form of snow enough water to flood the great rivers in spring: some of this latter water sinks underground, so that with this and the absorption of the heavy monsoon increment, the Indo-Gangetic Plain itself lies over a natural reservoir, from which its treasures can be recovered by the sinking of wells.

The heat experienced in India prevents meat from being a general article of food, and crops must be raised at both seasons of the year. This is especially the case when the population is as large as it is in parts of the Ganges Valley, and in those other districts where necessity is increased by the nature of the rains when they come—in two enormous bursts—when the half-yearly supply of 22 inches at Madras, for example, may fall in two showers with a fortnight in between.²

Thus nowhere else in the world is the food supply for a large population so dependent upon irrigation as in

¹ *Economic Geography* (John McFarlane).

² Actually forty-four inches a year. But the agricultural utility is influenced by the temperature, the soil—much of which is a hard rock, allowing a too easy run off—and the *régime* of the rains (see below).

India; it is therefore not surprising that at the present day this country possesses irrigation works on a greater and more successful scale than is found in any other land. It is said that during the last forty years the Government has ensured by the method of canal distribution alone water sufficient for the cultivation of more than 20,000,000 acres of territory.¹

The greater part of the water supply for irrigation in India is obtained by one or other of three methods. The first to be considered and the most successful is that introduced by its present British rulers, but the remaining two display no mean power of dealing with the matter, and have been in operation for centuries. Irrigation by storage dams and take-off canals largely supplies the Indo-Gangetic Plain, though in that section of it known as the United Provinces and elsewhere underground water is also recovered by well-digging; lastly, the water of the rainy season is stored in tanks, a name derived from a Portuguese word meaning 'wells,' and which rather inadequately describes the actual thing. Tanks are mainly employed in the non-porous crystalline regions of the southern portion of the peninsula and in Ceylon.

Before discussing in detail the three methods of water conservation and water recovery, something should be said concerning the irrigation facilities of the Indo-Gangetic Plain. On account of its enormous size it may be regarded as a vast stretch of river alluvium of great and, indeed, of unknown depth. It appears to have been formed by the filling in of a former gulf that once separated the Deccan from the mainland of the continent. The material represents the deposition of rivers originating mainly in the Himalaya Ranges, and as these were uplifted in Tertiary times the soil is a comparatively young deposit and exceedingly porous. However, two kinds of alluvium are distinguishable: a

¹ India's greatest dam, the Bhandardara dam, near Bombay, was opened in January, 1927.

coarse gravel which fringes the hills at the foot of the mountain girdle, the 'old' alluvium or *bhangar* and a much newer deposit of fine sand and some clay, the 'new' alluvium, or *khadar*. This clay is of great importance in the hydrography of the plain. Its presence or absence makes the sand more or less capable of storing water, and further, as it exists as pockets in the sand (*mota*) wells of considerable stability can be dug in the clay and filled by piercing through to the saturated sand. The level surface prevents the rain from running off, and consequently much of it percolates to the beds below. Rivers and canals assist, by leakage or seepage, in augmenting the underground water, so that the saturation level is often sufficiently near the surface to be 'tapped.' Thus the Indo-Gangetic Plain is an ideal locality for irrigation, nor are there lacking those alkaline tracts which irrigable and irrigated land of this description usually contains.

Another facility is, of course, the presence of great and perennial streams, fed by the glaciers or snows of some of the most lofty mountains in the world.

The method of irrigation employed when once the canals have been filled is that in common use whenever water reaches the cultivable area in channels or ditches. Banks of earth divide the land into compartments and water is allowed to run into them by the process of breaking the earth-wall and making a temporary diversion dam with the material removed. This is surface flooding, and is not without certain dangers which will be considered later. The three methods of storing or recovering the water must now be described.

1. *Irrigation by Barrage and Canal*

The source of the water is the snow upon the Himalaya Mountains, feeding great rivers which, after racing down the well-weathered slopes in deep gorges, slowly traverse immense lengths of plain.

In the north-west corner of India is the region known as the Punjab, or Land of the Five Rivers: namely, the Indus, Jhelum, Chenab, Ravi, and Sutlej. Half-way across the plain they gather into the one mighty stream of the Indus, as the united waters are now called. In the Punjab there is a small winter rainfall due to the passage of cyclones which, originating in Iran and Afghanistan, travel from west to east. Lower down the river the Indus plain is exceedingly arid and away from the rivers was formerly desert. Thus the Indus and its affluents were to the country what the Nile was to Egypt, except that there was not the same recurrent and wide inundation by the silt-laden flood. At the present time the area of desert has been much restricted and fertility assured by the construction of canals. These are of two types, the 'inundation' and the 'perennial' canal. Conservation of water by the former method has been long in use. Inundation canals merely collect the surplus waters of the flood, and for this purpose they are built more or less at right angles to the river. This method of irrigation is appropriate to the lower and flatter portions of the Indus Plain, namely, in Sind, though it reaches its greatest development where the rivers of the Punjab begin to converge to form the one, united stream. This is also the locality where the old alluvium begins to give place to the new. There are certain drawbacks connected with such canals. Rapid deposition of silt may partially choke them; the rise of the stream due to the melting of the snows may not be sufficient to reach them; the floods may be delayed till the crop season is over, necessitating the labour of lifting the water from the stream to the canals. For wheat-growing, a winter crop, the fallow land is flooded and the water the soil retains is generally sufficient.

The perennial canals may be regarded as strictly modern; they are much more ambitious. They are designed to supply water all the year round, and in consequence demand great engineering skill. The common essential is the barrier,

anicut or weir, built across the river valley in the neighbourhood of the lowland. The valley may be of the gorge type, in which case precautions have to be taken on account of the speed and strength of the river. If the valley be a wide one there is the tendency to silt. Sometimes the reservoir may be fed by nearly the whole body of water belonging to a river for part of its course; the canal upon the Upper Swat on the North-West Frontier burrows under the Malakand Pass by means of a tunnel two miles long, while other canals furnish further examples of engineering ingenuity.

Irrigation by means of perennial canals also has its dangers. Here the waters come to the cultivator without much labour on his part, and the high esteem in which he naturally holds it leads to over-irrigation and an incomplete draining after use or even to no draining at all. This is especially true where silt is the only method of manuring, and the clogged surface and unaërated soil which may result tend to bring about depreciation of the harvests both in quality and quantity.

While the loamy soil of the Punjab makes winter wheat a very profitable crop, for which the winter rains are generally sufficient, during the hot season cotton and sugar are raised with irrigation. There are here thousands of acres under sugar-cane, but the produce is mainly used at home, and the Punjab is not one of our chief sources of supply.

In Sind irrigation has so far been carried out by inundation, but the Sukkur Barrage on the Indus is to provide for perennial canals.¹ It is built in the form of two bridges, each five times the length of London Bridge, so wide is the river at this point. The estimated amount of desert to be reclaimed by this dam is 6,000,000 acres. The crops to be grown will be grain and cotton, and an annual yield of

¹ The Lloyd Barrage, named after Sir George, now Lord, Lloyd, one-time Governor of Bombay. Begun 1923, it is expected to be completed about 1934.

2,000,000 tons is anticipated. Something of the magnitude of these irrigating operations can be appreciated by the mere statement of the lengths of the main and distributing canals connected with this enormous barrage : over 850 and 1200 miles respectively. The estimated cost is £12,500,000.

The other great river of India is the Ganges, flowing across a plain of extraordinary fertility and sustaining a very large population. The villages of the Indian peasantry, the different patches of crops, the green rice fields, the ripe wheat and barley, the white poppies, the yellow mustard, etc., are familiar incidents in all pictures of rural Indian life. But even in the Ganges Plain, away from the water the desert would resume its own were it not for the artificial watering supplied by man. The system of canals is here repeated, but the nature of the soil allows of another aid.

In the northern hilly district of the Plain the irrigation is effected by canals of which one from Hardwar, where the Ganges leaves the mountains, is more than 1000 miles long. The other terminus is at Cawnpore. At Hardwar the canal takes the entire volume of the river, and this it carries sometimes above and sometimes below ground. When the waters have found their way back to the river bed, 20 miles below Hardwar, they undergo a second diversion. Distributing channels bear the waters of this system across the Plain of the Doab ('two rivers') between the Ganges and the Jumna in several thousand miles of branches. A feature of the irrigation is the method of water allotment. An extent of cultivable land is decided upon, and water given sufficient to produce a certain percentage of the possible cultivation. In this way more land receives attention than would be possible if the cultivation were more intense. It is an attempt to provide something for the many rather than much for the few. Actually, all risk of famine has now been removed from the Doab.

2. *Irrigation by Wells*

The various methods by means of which water collects in the subsoil have already been considered. It can be reached by sinking moderately deep wells to 50 or less feet below the surface. This form of water recovery is so much in vogue that the plain between Delhi and Benares is riddled like a sieve with these water-holes. The process of well-construction is somewhat as follows :—

Where there are pockets of clay in the sand a hole is dug in the clay to the required depth and water from the saturated sand around is admitted by means of a narrow boring and pipe, or by a mere narrowing of the well at its lower extremity, the clay floor being thus pierced to tap the saturated layers of sand below. The walls of the well are stronger when dug in the clay than when they merely consist of sand, and wells of this description are the more usual. They are known as 'spring' wells. The 'percolation' wells are dug in the gravel or sand where clay is absent. The bore extends to the saturated layers and the water percolates through the sides and base. A lining of brushwood is sometimes put down to filter the water on entering the well.

Wells may be temporary or permanent. In the Punjab the water-table is far below the surface and the wells have to be deep and the walls strong. They are therefore lined with masonry. Such a perennial well may cost £30 or more to construct, and in the Ganges Plain, where the water is easy to obtain, the wells are generally temporary, soon dug and usually abandoned after one season. Temporary wells have other advantages in addition to that of cheapness. They can be dug where required, and if a first choice of site be not successful, there is no great monetary loss. Also they can be dug in an emergency.

Land irrigated by wells is exempt from the extra tax placed upon that irrigated by other methods.

There are three ways of lifting the water from the well and

the choice depends upon the depth. When it is not far below the surface, a leather bag is let down from a lever balancing on a post and worked by a man : in other cases the rope and pulley method is used, the lifting power being supplied by bullocks which walk down an inclined plane. The water may be raised also by a 'Persian Wheel'; this consists of an endless chain upon which water-pots are fastened. The motive power is again supplied by bullocks, but the plane is replaced by a circular tract.

The recovered water is emptied into a prepared ditch or channel and when required is made to inundate the ground in the manner already described.

The system of well irrigation extends mainly over that part of the United Provinces lying between the Ganges and Gogra Rivers, and it is said that three-eighths of the artificial watering of India is carried out in the Indo-Gangetic Plain and by these methods. There is also some well irrigation in Madras and Bombay.

The crops produced are poppies for opium, and wheat and rice in the cold and hot seasons respectively. Patna rice has a special reputation as an article of export.

3. *Irrigation by Tanks*

The Deccan and Madras are dotted with thousands of tanks or reservoirs. They are formed by building an earthen bank across the outlet of a small valley or round a depression in the ground with the object of catching and retaining the summer rains. Distributing channels take the water from the tank to the fields, and after it has been used it is collected in a ditch and led to another tank at a lower level to be drawn off a second time, and so on. This frequently results in the formation of a chain of tanks connected, perhaps, by some stream. When a tank becomes silted up, another is built near by, and the old one converted into cultivable ground. The tanks may be from a few square yards to several square miles in size, but this method of distributing water

accounts for the number of village communities and the small holdings of land. Tank irrigation is a characteristic feature of the Native States of Hyderabad and Mysore, and this latter, with its 20,000 such reservoirs, is said to be the most prosperous Native State in India.

The three principal rivers of the plateau are the Godavari, Kistna, and Cauvery, all three practically unnavigable but of the greatest service for irrigation. Along their banks are numberless villages of small, palm-thatched huts. The crops reared are of the usual type—cotton, tobacco, rice, millet, saffron, castor oil plant. Otherwise the country is a cattle country.

The tanks rarely contain more than sufficient water for one year, and as recurring droughts are rather frequent this is the region too often the object of our 'Indian Famine' Funds. When the rains fail altogether famine follows wherever there is no irrigation, though the loss of life is not now nearly so great as formerly. This is due to the 'Famine Service' Organization, but the poverty caused by the drought is very great, as the cattle die in thousands because of the ruin of their proper grazing grounds. In Madras the plateau rivers form fertile deltas which have been irrigated by canals for many centuries. Those on the Cauvery Delta, for example, existed as long ago as A.D. 300. The head of water is obtained by building a weir or anicut across the river. Rice¹ is a chief feature of the cultivation, but other Deccan products are grown: e.g. castor oil. In the Madras plains irrigation provides for the tobacco of Trichinopoly, Tanjore, and Dindigul.

Before the War the total area of India irrigated by canals, tanks, and wells, was 18, 8, and 13 million acres respectively.²

¹ The building of a monster dam on the Cauvery River, in the Province of Mysore, has led to some trouble in the Madras Presidency. This great hold-up of the water, when completed (41,000,000 cubic feet), will seriously affect the irrigation of these rice-fields on the delta.

² Oxford Survey: *Asia*.

Fresh irrigation works on a large scale are again in progress.

Ceylon has been made to share with Java the traditions of a country in which every prospect pleases, a criticism on the pleasantness of its climate and wealth of its vegetation. But geographically it is a severed portion of the Deccan and Madras, though nearer to the equator. In spite of the high temperature and generally abundant rainfall over the greater part of its surface, there is one area of drought. This occurs in the northern low-lying land, where the rains are light. Here are the remains of long disused irrigation works, temples and large buildings, pointing to a former prosperity very much at variance with its present poverty and small population.¹ The irrigation works are mainly tanks, one of which is said to date back to 504 B.C. Though so long out of use and in disrepair the tanks can and are being restored. They are sometimes very large, for instance the Kalawewa tank has a sectional area of 4425 acres, and a depth of 22 feet at the point where it can be drained.

When the seasonal rainfall is insufficient to fill the large tanks a river may be diverted from its course. Even in the wetter part of the island some irrigation is necessary, for the main food is rice and that requires a longer drenching with water than the spasmodic monsoon rains permit. In the mountainous part of the country there are minutely terraced fields covering the slopes, and a stream at some high level has its water taken off by a canal winding round the mountain, from which it may be given to the lower lands.

The same terrace irrigation is found on the Himalayan slopes. In this way the 'vale' of Kashmir is watered by artificial streams brought in trenches from snow-fed rivers often very far away. Terraces are planted with almond

¹ The ruin of the tanks seems to have been due to Tamil invasions, either by wanton destruction or by removal of the custodians of the tanks.

groves, grain, and the vine. The mountain Native States of Nepal and Bhutan are described as resembling gigantic stairways, each step glimmering with the water brought thither from the mountain streams to saturate the standing rice. Irrigation is similarly practised in the lofty valleys where the Himalaya and the Hindu Kush ranges meet.

CHINA

The population of China is so dense that in spite of the extraordinarily heavy summer rainfall, land generally regarded as useless must be put under cultivation. Hence dry, steep hillsides have become terraces of growing crops to which water from some river or supply in the valley below is raised by the wheel-and-bucket method from terrace to terrace for distribution by smaller wheels at each level. The necessity for irrigation is due to the porosity of the soil, which in certain localities too easily allows the rainfall to sink below the ground. Many parts of China, like certain areas in the Ganges Plain, are studded with water-holes. This is especially the case in the 'loess'¹ district of North China, the basin of the eastern section of the Hwang-ho. The depth of the loess may be several thousand feet, and the rivers have cut down their beds to the underlying solid rock. They flow in cañon-like gorges that carve the country into isolated blocks, a process assisted by the forms taken during the natural weathering. Where irrigation is possible, the water is lifted to the summits of the blocks by water-wheels, etc. The labour is so great that nothing must be wasted, hence the prevalence of spade culture and intensive farming. The main crops are wheat, barley, millet, maize, cotton,

¹ Loess is a loam, rich in lime and free from pebbles; it appears to have reached its present position as a fine dust, the transport having been effected by winds. Much of the Chinese loess comes from the desert, and hence is 'virgin' and rich. Its porosity, however, is a distinct disadvantage in some cases, e.g. rice.

tobacco, and pulse. The porous soil is unsuitable for rice, since the roots of this plant require to stand in water for at least the earlier stages of their growth. Wheat grown on the steep valley floors flourishes here to such an extent that it replaces rice as a staple diet. Each winter the dust storms give a fine top dressing.

The same dust becomes silt in the Hwang-ho or Yellow River, a stream too swift and shallow for much navigation. The propensity to change its course which has given to its lower reaches the ominous name of 'China's Sorrow' materially affects the amount of irrigation that can be practised along its immediate banks.

The Valley of the Wei-ho,¹ the main tributary of the Hwang-ho, supports a large population equally dependent upon irrigated agriculture. This favoured Valley is an age-old caravan route on the edge of the loess—and is said to have been the gateway by which the original Chinese entered the region. Here also, there is too little water for much rice and the staple food is wheat, beans, peas. Irrigated cotton and tobacco are important crops of Shensi and Kansu respectively.

In South China the province of Szechwan, watered by the streams of the upper Yangtze-kiang, is known as the 'Red Basin' on account of the colour of its soil.² The gigantic irrigation works, which were carried out by the two Lis about 200 B.C., have already been considered. The method of controlling the Min-ho for this purpose is in all essentials the same to-day as when it was first conceived, and the previous short account may now be amplified.

From A.D. 1573 the longitudinal dykes in mid-stream were replaced by a long tongue of boulders encased by

¹ Wei means 'clear,' so that the Wei-ho signifies 'Clear River,' a comment upon the turbid Hwang-ho to which it is tributary. In Northern China 'ho' stands for 'river,' and in Southern China 'kiang' is thus used. In southern regions where the northern 'ho' occurs, the historian may get a hint regarding the direction from which conquest has been effected.

² See page 52.

crates of plaited bamboo. This arrangement has proved to resist steadily the summer freshets, though inevitable repairs can be easily effected during the winter low water. Flood-gates permit the water to be directed to either side of the barrier, and subsidiary channels are dyked out on the sides of the two primary ones. Two miles lower down the stream from the point of first separation the two original channels are each again divided, so that there are now four. This process is continued until the channels are very numerous and have attained the dimensions of brooks. In this way the original force of the water is tremendously modified and by means of sluices and ditches it can, without danger, be directed into the fields.

The annual opening of the main dyke takes place about the time of our Easter, when the water of course is still low. Actually it coincides with the Ching Ming Festival, instituted by the Emperor of that name about 2800 B.C. The dykes are carefully examined by a Government Inspector, and when he is satisfied that everything is in good order and repair, he holds a ceremonial service in the Temple of Li, after which the barrier is removed from the main river and the water floods all over the prepared course as the stream gradually rises.

The climate of the Red Basin is sub-tropical, and the fertility of the soil and facility for irrigation in some localities permit the raising of five crops a year. Water is often lifted to the terraced hillsides by means of water-wheels, after which irrigation is performed in the manner customary for this method of cultivation.

The Plain of Chengtufu in the Red Basin is the delta of the Min-ho and other streams directly or indirectly tributary to the Yangtze-kiang. The Min provides for some of the finest irrigation in the world, so that from Chengtufu to Suifu, where it joins the Yangtze, the population is estimated at the great density of 2000 persons to the square mile, and the villages are literally 'continuous' all the way.

The climate and soil of the Red Basin allow the growth of almost any kind of grain—for it must not be forgotten that there is some winter rain:¹ but in addition to rice,² maize, wheat, there are other irrigated crops of sugar and tobacco. The difficulties of navigation upon the Yangtze make transport rates high, and none of the above-mentioned commodities is exported. But probably all the food grown is necessary to satisfy the enormous hunger of the Province.

Irrigation has made Szechwan the richest Province in China, and it has gained the reputation for being the most productive land on the face of the globe. It is interesting to know that the pioneers of Australian Irrigation first made a visit to this country before entering upon the undertaking which was to revolutionize that isolated continent of the Old World.³

BIBLIOGRAPHY

COLONEL SIR THOMAS HOLDICH : *India* (Clarendon Press).

OXFORD SURVEY OF THE BRITISH EMPIRE : *Asia* (Clarendon Press).

A. V. WILLIAMSON : "Irrigation of the Indo-Gangetic Plain" (*Geographical Journal*, Vol. LXV, No. 2).

ARCHIBALD LITTLE : *The Far East* (Clarendon Press).

¹ See page 52.

² The rice of Szechwan is mainly hill rice, which like the tea of the region, also a hillside cultivation, requires its roots to be drained.

³ See page 185 *et seq.*

PART IV

MODERN IRRIGATION : THE NEW WORLD

In this category of the "New World" there have been included the great Continents, or such parts of them as were discovered and developed by the White Man at the time of, or subsequent to, the discoveries of the Fifteenth Century. These lands share this much in common—the use of modern systems of irrigation as a means of opening up, exploiting, and developing their agricultural possibilities for the enrichment of the dominant race.

CHAPTER XIV

NORTH AMERICA

THE UNITED STATES—THE ARID WEST

IN the Western States of North America there are over nineteen million acres of land under irrigation¹ and it is stated that enormous as is the value of the mineral wealth in this part of the country, the wealth derived from the irrigated farms is even greater.

The arid lands of the United States lie west of the 100th meridian W. and south of the 49th parallel of latitude. From the eastern boundary the ground gradually rises to the foothills of the Rocky Mountains, and though most of it is from two to six thousand feet high, on account of its enormous extent its geographical description is that of High Plains. Westward of the Rocky Mountains lie the Pacific Ranges, running more or less parallel to, and in general so near the coast, that the coastal plains are few, relatively small, and isolated. Between these two mighty chains is a confusion of intermont² plateaux and basins, only receiving sea winds which have been largely drained by the western heights, and which, as a consequence of the compression and warming of the air attendant upon its descent on the leeward side, are additionally capable of retaining and absorbing moisture.

Aridity elsewhere in this land depends upon the seasonal character of its rainfall, which here, as in the Old World, conspires with the temperature to render artificial watering imperatively necessary for the cultivation of crops. On

¹ Census Report, 1920.

² That is, "between the mountains."

most of the coast it is of the Mediterranean type, a winter rain and summer drought. In Arizona and New Mexico the great size of the continent and the barrier of the Rocky Mountains have produced a continental climate of extreme aridity in place of the type which the latitude demands. The region, as a whole, however, possesses a number of large rivers originating in the snow and rain of the Rocky and Pacific Ranges; unfortunately the annual flooding that takes place during the spring and early summer and the lowness of the streams at other seasons make water-storage necessary for agriculture.

The soil of this Arid West is in general extremely fertile; like that of the Indo-Gangetic Plain it has been derived from the wreck of mountains uplifted in times regarded as geologically recent. But though the soil is very porous, the configuration of the surface is markedly different from that of the Indian Plain. Here there are no heavy monsoon rains, and weathering has been slight in comparison with river erosion in the but loosely consolidated soil. In consequence the surface has been carved into the steep gullies known as cañons, of which one, the Colorado Cañon, contains a river which flows in a narrow gorge a mile high. Clearly a cañon country of this description cannot be watered directly from its stream and it is on this account that the Columbia River, sunk deeply in basalt, is of little utility for irrigation, though some pumping plant has been installed.

The difficulties of effective irrigation are further increased by the 'basin' character of much of the land to which allusion has already been made. For the water that sinks below the soil at the piedmont must reappear or at any rate be not far below the surface at the centre of the basin. This produces injurious water-logging exemplified in the lakes and swamps of the Great Basin of Utah and the Grand Valley of California.

The rivers furnish the main part of the water supply, but as we have seen, the nature of the régime necessitates water

storage in a reservoir of some kind behind a dam. A considerable use is also made of underground water, recovered by boring, and in some localities pumps are employed to lift both well- and river-water to the surface of the fields.

A crude irrigation was practised in the south-western corner of this territory by the Indians before the Conquest. Spanish settlers, especially in California, continued the Indian tradition, but the first serious attempts in 'modern' times to open up this arid region was made by a sect of people known as the 'Mormons.' This community was organized in 1830 by a certain Joseph Smith. The peculiar tenets of their creed had brought the Mormons into antagonism with the authorities and they decided to seek some uninhabited part of the continent where they could profess their beliefs undisturbed. The great trek westward was accomplished under the leadership of Brigham Young, and the colony finally settled a few miles from the Great Salt Lake, a name of the utmost significance in a country of alkaline desert (1847). Here they began to lay the foundations of their new home, Salt Lake City, to-day recognized as one of the most beautiful cities in the States.

This salt-desert oasis which was first developed by the Mormons is a part of the Great Basin whose eastern rim is the range of the Wasatch Mountains. Here an annual rainfall of about 16 inches, chiefly occurring in winter and spring, is supplemented by numerous streams flowing from the heights. A feature of some importance is the fact that the upper slopes of the mountains are forested, a circumstance tending to retard the melting of the snows and prevent disastrous floods in spring.

The irrigated areas are on the foothill slopes, for on account of reasons already mentioned, much of the Basin floor is water-logged and useless. This same floor appears to be the bed of an enormous but now vanished inland sea, the Lake Bonneville of the geologists, of which the Great

Salt Lake is but a feeble remnant. Owing to its lacustrine nature, the soil is extremely fertile, being rich in phosphates and potash, and this in conjunction with the hot, dry summer makes it peculiarly adapted to the cultivation of wheat.

In this spot, unique alike in its isolation and its potentialities, the Mormons settled themselves as an agricultural community and began to reclaim the desert. They employed the method of irrigation and alfalfa-growing, the latter for fodder as well as soil enrichment. It was not long before part of the waste was converted into beautiful gardens planted with fruit trees, and fields covered with useful crops.

As their prosperity and their families increased they ultimately found it necessary either to spread to new lands or to enlarge their existing operations. Idaho, Wyoming, and other places where cultivation could be carried on by Mormon methods eventually received small colonies, while at home, with their paramount purpose of self-sufficiency and self-development, they began to bring their activities into line with modern industries. The new railway (1869) perhaps forced them into touch with the outside world, and conversion of the products of the land into forms suitable for export has become a leading feature of their community enterprises. To-day, alfalfa and sugar-beet are the chief crops after wheat, but much of this latter is now raised by dry-farming. Fruit production includes apples and peaches.

The agricultural fame of the Utah Colony was soon recognised far and wide. In 1848 gold was discovered in California; the following year witnessed the wild rush thither of the ever-famous 'forty-niners' in search of quickly gained fortunes. One route to the gold-fields led by the Great Salt Lake, and the work of the Mormons must have shown to the greater advantage on account of its desert environment. On their return home, the successful miners

carried to their countrymen news of a surer means of prosperity than could be dug from auriferous sand or gold-bearing lode in the ancient rocks.

The completion of the Union Pacific—Central Pacific Railway to the Pacific Coast (1869) facilitated a renewed emigration to the Far West, and some cultivation by means of artificial watering was begun in nearly all the arid territories. Twenty years later over fifty thousand farms had been established with temporary irrigation works manipulated by the individual settlers or groups of settlers. The method at first employed was that of simple storage of the spring floods. A suitable site was chosen where some river issued from the neighbouring hills in a narrow gorge. Here a crude dam was constructed and small earth-banked trenches took off the water from the reservoir so made. The amount of land irrigated in this way was rather limited and later (1909) cultivation stretched farther from the streams, the water being led in large canals to feed irrigation ditches, owned as formerly by particular farmers or small groups of farmers. The canals were built at the expense of different communities or incorporated companies.

This method of irrigation is in operation in the triangle between the St. Anthony and Idaho Falls and the South Fork River, and it serves a large number of farms on the Snake River Plain of Idaho, where hay, especially alfalfa hay, is the predominating crop, though there is also some irrigated grain and fruit growing.

The lifting of river water by the agency of pumps occurs in several parts of the States. In North Dakota, for example, water is taken from the Missouri by the use of a pumping apparatus erected upon a floating barge and worked by electricity. The power is obtained from a rather poor lignite coal which happens to be in the neighbourhood. The water is lifted in this way into a reservoir situated at a higher level than the irrigable land and then distributed by gravity. The irrigation responsible for the rice crops of

Louisiana and Texas is largely effected by this method. A difficulty met with here is the low level of the country which allows salt water to enter the streams at times to replace the fresh water removed by pumping. Along the course of the Rio Grande in Texas storage is often possible, but not in operation. This is because the river in this part of its course is an international boundary and at present the two governments have been unable to agree as to a just division of the water-rights.¹

The recovery of ground water by the means of wells, both flowing and pumped, forms a notable contribution to the irrigation process. Seven per cent. of the total irrigation of the country was supplied by wells in 1919.² The rice crops of Arkansas rely almost entirely upon well-water, while those of Louisiana and Texas use it to an appreciable extent.

In course of time the United States Government turned its attention to the possibilities of the arid West. It seemed likely to offer some solution to the problem of 'crowding' in the Eastern States, and in 1902 a 'Reclamation Act' was passed in Congress during the Presidency of Roosevelt. From this measure resulted the creation of the Bureau of Reclamation and Plant Industry, the business of whose departments was not only to search for irrigable land, to project and construct reservoir dams and irrigation plant generally, but also to investigate what kind of cultivation, fruit trees, root crops, cereals, or merely pasture for ranching would be best adapted to the different exposures and soils. With this object in view, botanists have been sent far afield to the Mediterranean countries of Europe in search of suitable plants and seeds, and experiments both ingenious and diverse have been tried in planting non-indigenous growths in these dry wastes. The scheme, whose conception is of an extraordinary thoroughness, includes the establishment of

¹ But see page 167 for details of the Rio Grande project.

² Fourteenth Census Report, 1920.

Demonstration Farms where settlers may see the new scientific methods of agriculture in operation.

As regards the financial side, it was decided by the Act that the works which would be of necessity very costly (the Salt River Irrigation Project alone cost about £2,500,000) should be paid for by the sale of public lands in sixteen of the arid Western States,¹ and that the water-users should repay the Government in ten annual instalments (in 1914 and in 1926 the number was raised to twenty and to forty respectively). Since 1920 contributions have also been levied upon oil and other mineral rights.

The 'projects' under the authority are some twenty-six in number, no two of which are alike. The difficulties of construction were very great and the following account of some of them gives a slight idea as to the tremendous obstacles to be overcome and what has actually been accomplished.

On the Salt River, in the Desert of Arizona, that "land that God forgot," is the great Roosevelt Dam² by means of which a valley in the Upper Salt River has been converted into a lake 18,100 acres in area, holding sufficient water to irrigate 213,000 acres and capable of storing the entire flow of the stream above it. There is here provision for two years should further increment fail. The masonry of the dam is 280 feet high, 235 feet long on the bottom and 1125 feet along the top: at its base the dam wall is 158 feet thick.¹ This great barrier intercepts the river across a deep but relatively narrow mountain gorge, and is built both at the bottom and sides into solid rock. It is situated in the midst of extremely rugged and mountainous country, and before the work could be begun, roads many miles in length had to be cut into the rock itself for the purpose of transporting machinery. Apparatus for developing hydro-electric power was installed at the dam, and used with the aid of the

¹ Publications of the Bureau of Reclamation, 1926.

² Completed 1911. Appropriately named after the famous president.

material obtained from quarrying the rock in the mill required for making cement. On account of the distance from the nearest town and railway (70 and 40 miles respectively), a large proportion of the food supplied to the workers at the dam had to be grown near by, necessitating the institution of a crude irrigation plant. Most of the unskilled labour employed was supplied by the Apache Indians.

The dam feeds 800 miles of cement-lined canals; these are bordered with trees to diminish the evaporation in this cloudless country. Most of the soil irrigated lies below the level of the reservoir, but 50,000 acres above the level are also irrigated. To effect this the water is sent through a special canal $18\frac{1}{2}$ miles long; it is then raised by means of pumps worked by turbines.

Many of the barrages are of similar construction, but some have peculiarities of their own. Among these may be mentioned those in the Great Basin, itself composed of a number of smaller basins the lowest parts of which are often known as 'sinks.' Irrigation is effected by damming the river flowing into the sink so that during the spring floods the 'natural meadows' bordering the stream are watered by the overflow. Elsewhere the land is sometimes brought under cultivation by bringing in water from outside. Thus the Strawberry Reservoir in the Colorado River drainage system supplies the Basin with water by means of a tunnel discharging into the Spanish Fork River.

In western Colorado the irrigable land consists of a broad, alluvial and therefore fertile, plain known as the Uncompahgre Valley. It is watered by a small and totally inadequate stream, the region also being very dry. Some miles away in a parallel valley is the Gunnison River, a large and vigorous torrent, but one which flows in a deep cañon. Here there is plenty of water but no land upon which to use it. A mountain range separates the two regions but connection is made by a six-mile tunnel which carries the water of the Gunnison to the Uncompahgre Desert.

This formerly useless territory is now being very successfully cultivated.

Another of these monster undertakings is the Arizona-California, Yuma project, of which the Laguna Diversion Dam is a special feature. Owing to geographical circumstances, the main canal must be on the Californian side of the Colorado River near Yuma, where the irrigable land, which includes territory of the Yuma Indian Reservations, is of less extent than on the Arizona side. The difficulty is met by means of an enormous inverted syphon which passes under the river and thus carries water to Arizona, where it is distributed. A pumping plant also lifts it to the Yuma mesa, which is considered an ideal locality for citrus growing.

Some other eminently notable irrigation dams are in Idaho (Arrowrock), Montana (Sun River), New Mexico (Elephant Butte), Wyoming (Shoshone), etc. This latter dam is 328 feet high. All these are built across deep and relatively narrow gorges, but there are others spanning wide, open valleys where length rather than height is the dominating factor. Thus the Hondo Dam in New Mexico is only 25 feet high, but it extends for three miles: the Nelson Reservoir Dam in Montana is 39 feet high, but four miles long. On the South Platte River, which gives water to Colorado and a small portion of Nebraska, the storage is effected by many small reservoirs in place of one large one.

The distribution of the storage water is well illustrated by the irrigation of the arid plain round Denver. This plain is crossed by the South Fork of the Platte River, which here has a rapid fall. A ditch as large as a canal takes off from the reservoir and is so cut that it forms an angle with the river at a slope sufficient to give a slow current. The ground between the ditch and the stream is lower than the ditch, so that subsidiary channels can easily lead water from it to supply the farms established in the area. When a field needs water the ditch is tapped in the usual

way, and the surface flooded, or the water may be led into little furrows a few feet apart.¹

The farmer is taxed for the use of the water, but at a rate far below the benefit he receives. Cultivation in and around Denver results in the growing of fodder to provide food for cattle in place of the normal grazing for sheep pasture. Wherever the waters of the rivers are led out into the fields, there men form settlements, often small cities. Such, among others, has been the case with Colorado, Cheyenne, and Laramie.

This irrigation is not effected without risks. The desert soil is often porous, and the water easily sinks through till brought up against a buried layer of impervious rock. In time this may lead to an accumulation of so large a quantity of ground water that it may spread to lower lands and, by water-logging, bring about the ruin of crops. The Federal Government is held responsible for injury of this character and must deal with it. This necessitates draining by a system of pumping which is frequently very expensive, though in the case of the Salt River Valley, the evil is made to supply its own remedy. There the surface of the ground water is lowered by the digging of wells and open ditches, which have the further advantage of providing extra supplies for irrigation.

Another risk that must be taken when water reclaims a porous soil is the formation of 'alkali spots.' The underground water may dissolve much saline matter, such as sodium nitrate, and bearing this in solution it may rise towards the surface by the process known as capillarity. When the water evaporates under the influence of the sun and the dry air, it will leave its dissolved load as a solid precipitate, forming a covering detrimental to plant growth. The 'alkali' deserts may have originated in this way. The methods of reclaiming such areas have already been dealt

¹ For similar concrete examples of this process of 'irrigation by gravity' in the Old World see pages 82, 88.

with,¹ but in California and in north-western Canada, in the very heart of well irrigated and fertile fruit-growing regions 'alkali spots' may be found which are poisonous to vegetation and unfortunately owe their origin to the processes of irrigation.²

Before passing on to the actual agriculture of certain typical areas, the Columbia Basin Irrigation Project should perhaps be mentioned. At present it is still in the stage of preliminary investigation, but if carried through, it will make a considerable extension to the existing irrigated areas in that State. A suggestion is to utilize the Upper Coulee, a dry valley which was once part of the bed of the Columbia River, as a reservoir for water.

At the other extremity of the western coast lands lies California, with its three regions of special fertility. The Californian Valley is a tract of country between the Sierra Nevada and the Coast Range, the wall of the latter being broken at the Golden Gate, where the streams that water the valley find their way to the sea. The height of the Sierra causes condensation of much of the rain which has escaped the lower ranges on the sea-board, and numerous tributaries flow down them to be gathered up by the Sacramento and San Joaquin Rivers. The Sierra is highest where the tributaries of the southern river rise, and the slopes near the crest of the range lack the tree growth that is so conspicuous farther north. This has resulted in extensive weathering of the surface rock, whose débris has been carried down by mountain torrents and spread out in unconsolidated alluvial fans upon the valley floor. These fans are of course fertile deltas and form the irrigable area; the streams lose so much water in this way before they reach the centre of the valley that Lake Tulare is becoming gradually smaller and may one day disappear. This will increase the agricultural value of the region, naturally a tule-covered marsh, of which

¹ See page 34. Compare also page 182, footnote.

² See Note, page 157.

much has already been reclaimed for farming. The reclaiming process is also assisted by the digging of wells, which here, as elsewhere, helps to reduce the injurious ground-water.

In the northern section of the Valley, the forest protection has resulted in less erosion on the heights and in consequence the foothills of the tributaries of the Sacramento have not the same richness of soil as in the region just considered. Here crop rotation is practised and, besides alfalfa and the associated dairy industry, the annual inundation of the floor has led to the cultivation of much rice. Where the coastal streams of San Francisco Bay emerge from their mountain courses there is a second area where annual inundations reinforce the ground water of the Valley floor and again flowing and pumped wells recover the water for irrigation.

The second notable irrigation area in the State of California is in the Los Angeles district. This region is naturally desert, but careful use of its rivers, Santa Ana, Santa Clara, etc., has converted it into one of the garden spots of the world. The porous soil contains much well water and the San Diego Dam places the irrigation facilities upon more modern lines. Fruits are grown in great quantity, those of the citrus family, perhaps, predominating.

Still further south is the Imperial Valley of California, at the head of the Gulf of the same name. Irrigation here is the last effort of the Colorado River, and it differs from the remaining five Colorado Basin enterprises¹ in being a private undertaking, not under the control of the Federal Government.

The irrigated area consists of an ancient and a modern delta built up by the river and separated by a belt of slightly higher ground. The ancient delta is more popularly known as the Salton Sink, and lies 200 to 300 feet below sea level.

¹ The Salt River (Arizona), the Yuma (Arizona-California), the Grand Valley (Colorado), the Uncompahgre (Colorado), the Strawberry Valley (Utah) projects.

The greater part of the modern delta is in the Republic of Mexico, but as it belongs by climate and configuration as well as geological history to the Imperial Valley, it will be considered at this place.

The Salton Sink, as a garden truly sunk in the desert, naturally attracted the imagination of the first enlightened visitor to these arid lands, and here again the gold rush of '49 played its part. Dr. Wozencraft, one of the original forty-niners, went to inspect it, and believed that water could be brought from the Colorado to the rich, but thirsty, soil. His story is one of high idealism but practical failure, though he did much to familiarize men's minds with the irrigable possibilities of this region. Political troubles arising from the Civil and Spanish-American Wars caused any serious investigation to be deferred from time to time, and it was not until 1900 that engineering works were begun. The auspices were most promising, for George Chaffey,¹ at once a wealthy man and an irrigation engineer of repute, received the contract and also gave a very necessary financial backing. Chaffey already possessed considerable experience in desert reclamation, for he had worked for the Australian Government at Mildura.² His diversion canal was ready by 1901, and in May of that year water began to flow upon the desert lands of the Salton Sink, and more than 400 miles of canals and laterals had been constructed. The take-off is on the United States side of the river: the canal goes a few miles into Mexican territory and back again.

Chaffey's business was the erection of a diversion dam and canal, and here his responsibility ended. The Reclamation Service Bureau, surveying the completed enterprise, felt called upon to utter some gloomy warnings. According to

¹ Freeman spells the name 'Chaffee' and alludes to the 'Chaffee Gate.' F. Myers and the Australian League pamphlets give the other rendering.

² See page 185 *et seq.*

its experts a diversion dam upon such a mighty river as the Colorado ought to be supplemented with a flood dam to cope with the spring rise of the stream. Further, they considered a possible danger lay in the insufficient arrangements for removing the surplus water after irrigation. Neglect in this respect might and actually did cause a rise in the water-table or saturation layer underground, with a corresponding water-logging of the plant roots. Another possibility was the formation of 'alkali spots,' but what proved in the sequel to be an over-emphasis on this danger led to an unjustifiable confidence in other respects. For at the present time thousands of acres of good desert soil which water had reclaimed have relapsed into worthlessness through drainage deficiencies, and are now being reclaimed a second time by precisely opposite methods.

The danger to be apprehended by the unbridled Colorado was far more serious, but equally unheeded, and in 1905 the threatened calamity took place. Its magnitude and the very great likelihood of its recurrence may make a few details not inappropriate.

In 1904 the waters of the diversion canal were found to be insufficient to supply the full needs of the valley, excessive deposition of silt in the river having partially closed the intake. It was decided to add to the available amount by tapping some other portion of the main stream in the vicinity. The Federal Government, however, forbade this operation on the ground that quite sufficient water was already being removed from a river still technically regarded as navigable. The result was a contract between the Imperial Valley Irrigation District and General Diaz, President of the Mexican Republic, for the use of water diverted on the Mexican side of the International Boundary on the basis of equality in irrigation usage. A cut was made in the soft earth on the Mexican side (October, 1904), whereby water was provided for the following months of November, December, and January. It was intended to close this cut in

February before the spring floods, but some unexpected risings interfered with and hampered the work and the closing of the breach was not finally attempted until the end of March. The delay and difficulty in the closure and the real necessity for haste led to faulty construction and the use of material not nearly strong enough, and over which, when the floods began, the river triumphed powerfully. One day, without warning, the Colorado poured its entire waters into the Salton Sink. The passage took place by two channels winding through the reclaimed lands, but the damage was less than might have been expected since the new rivers scooped out for themselves deep gorges in the soft and unconsolidated clay and sand. In these channels the waters confined themselves : away from their banks the usual irrigation activities continued unchecked.

This unexpected and successful geographical operation of gorge-making has furnished a 'living' example of the similar operations of former times, the results of which alone are with us now, but, scientifically interesting as the visible process must be, the damage done and still more the threat of further damage to the prosperity of the valley is by no means compensated.

The first attempts to restore the river to its old course were entirely futile, and the floods of 1906 produced a second inundation. The waters of the 'Salton Sea' in the centre of the Sink were so augmented that the line of the Southern Pacific Railway became threatened, thus inducing the Company to come to the rescue of the valley. At a great expense, which the Federal Government partly defrayed, the engineers of the Company succeeded in closing the breach (1907).

At the present time the Colorado is controlled in the Imperial Valley by the temporary policy of high and strong levee-erection at points considered dangerous. But the enormous amount of silt that the flooded river carries, greater, in fact, than that borne by any other river in the

United States, is continually raising the level of its bed. This feature in the régime of the stream introduces trouble of a special character, and actually in 1909 a three years' deposition of silt enabled it to pour its flood waters into one of its old high-water channels, and so into the broad, shallow expanse of Volcano Lake. This lake is on the modern delta, and the waters of the Colorado drained from it by innumerable channels into the Gulf. Vain attempts were made to confine them to their old course after this 'diversion,' and, finally, a dam was constructed to prevent them from at least re-entering the lake (1922). This dam is not considered very secure, and experts state that the silt-building, which is out of human control, may cause similar catastrophes at any time and in any place. The single and only efficient remedy prescribed is that of constructing a flood-dam in the cañon section of the river, but the cañon country is outside the State of California and any undertaking of this nature would have to be an affair of the Federal Government. The expense of such a barrage would necessarily be very great, and so far no more has been accomplished than a survey of the ground with the object of selecting a suitable position for the dam. Meanwhile the make-shift policy alluded to continues, and the newly created Salton Sea covers 400 square miles of what might have been good, irrigable land. Moreover, as its present dimensions are the result of overflows which only lasted for a portion of two seasons' floods, another and perhaps greater accident to the canal walls might have still more disastrous consequences.

In spite of the difficulties and dangers attending the establishment of the Imperial Valley District Irrigation, the high summer temperature so advantageous for the growing of crops (89° F.) and the extraordinary fertility of the deltaic soil have made for steady progress since its earliest days. The position is not unlike that found in other lands where fertile tracts of country clothe the sides of a dormant volcano, to whose devastating outpourings, indeed, the

fertility is primarily due. Half a million acres are under the ditch on the U.S.A. side, yielding an average annual crop valued at £12,500,000, while more than half this acreage on the Mexican side gives crops whose value is about one-third that sum. The Mexican irrigated district has been developed by United States money, machinery and methods, and in addition the harvest is marketed across the International Boundary. The southern estates are larger than those upon the United States side, and for various reasons connected with their somewhat later initial development are better managed and yield a better return as far as cotton, the premier crop of both districts, is concerned. The kind grown is the long staple of the Egyptian variety, and the cotton-fields between Calexico, just within the U.S.A. boundary, and the Gulf are continuous, whereas the Imperial Valley cotton is in isolated patches. Other important crops are those of the usual Mediterranean type: grape-fruit, melons, cantaloups, lettuce, alfalfa.

The greater part of the irrigation of California is under private control, and has been in progress for more than fifty years. Much of the experimental work which resulted in the introduction of crops from the Mediterranean lands of the Old World was carried out here. The splendour of its fruits—figs, peaches, apricots, apples, and oranges—in striking contrast to the prevailing desert beyond reach of the water, has made the pioneer work a romance of absorbing interest.

The short summary of the chief irrigation areas in the United States given below is adapted from the 1920 Report.

It will be noticed that alfalfa is the largest crop grown. This is on account of its surpassing utility as a fodder, and the nature of the desert soil in which other crops would not thrive so well.

The order of the crops is the order of the number of acres cultivated. Fruit is grouped according to the number of trees. In the Report maize is sometimes described as *corn* and a distinction is made between plums and prunes.

NORTH AMERICA

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	% of Area Irrigated in 1919.	Main Irrigated Areas.	Main Irrigated Crops.
CENTRAL STATES :			
N. Dakota .	0.1	Neighbourhood of junction of Rivers Missouri and Yellowstone.	Spring wheat, oats, rye, hay, barley, cultivated and prairie grasses.
S. Dakota .	0.5	Black Hills Tributaries of the Cheyenne River.	Alfalfa, spring wheat, small grains and grass for forage, sugar beet.
Nebraska .	2.3	North Platte River round Scott's Bluff, North Platte, and Dawson.	Alfalfa, sugar beet, corn, oats, winter wheat, spring wheat, potatoes, forage crops.
Kansas .	0.2	Strip of riverine land W. of 100°W. on the River Arkansas: includes Syracuse, Garden City, Gray.	Alfalfa, winter wheat, forage crops, barley, oats, sugar beet.
Oklahoma .	less than 0.1	Tributaries of the Rivers Arkansas and Red: along Canadian and Cimarron Rivers.	<i>Unstated in Report</i> (maize, cotton).
Arkansas .	0.8	In the fork of White and Arkansas Rivers. In the fork of the Cache and L'Anguille-St. Francis Rivers.	<i>Unstated in Report</i> (maize, cotton).
Texas .	3.1	Rio Grande and its tributaries. Red and Canadian Rivers. Along streams flowing directly to the Gulf of Mexico.	Rough rice, maize, cotton, alfalfa, forage crops, winter wheat, vegetables.

THE THIRSTY EARTH

	% of Area Irrigated in 1919.	Main Irrigated Areas.	Main Irrigated Crops.
CENTRAL STATES—(continued):			
Louisiana	2.4	S.W. corner of the State :—between the lower Sabine and Atchafalaya Rivers.	<i>Unstated in Report</i> (maize, cotton).
MOUNTAIN STATES :			
Montana	8.8	Roughly the basin of the Missouri between the Milk and Yellowstone Rivers and mainly west of 108° W. to Missoula and the State boundary.	Alfalfa, prairie grasses, spring wheat, timothy and clover grasses, oats, winter wheat, peas and beans, sugar beet, vegetables. Apples, cherries.
Idaho	13.0	Valley between the Upper Snake River and its tributary the Salmon.	Alfalfa, spring wheat, prairie grasses, sugar beet, potatoes, oats, winter wheat, barley. Apples, plums and prunes, and peaches.
Wyoming	6.3	Upper Yellowstone and North Platte Rivers and tributaries between the Big Horn and Laramie Mountains. Green River tributaries.	Alfalfa, small grasses for hay, spring wheat, oats, potatoes, barley, corn, winter wheat, sugar beet.
Colorado	17.4	Four areas. Valley of the South Platte round Denver; down the Arkansas Valley from Canon City; head waters of the Grand and Gunnison Rivers.	Alfalfa, spring wheat, sugar beet, winter wheat, timothy and clover grasses, oats, barley, maize, potatoes. Apples, peaches, cherries, pears, plums and prunes.

NORTH AMERICA

155

	% of Area Irrigated in 1919.	Main Irrigated Areas.	Main Irrigated Crops.
MOUNTAIN STATES—(continued):			
Utah	7.1	Generally west of the Wasatch Mountains to Sevier, Utah and Great Salt Lakes.	Alfalfa, sugar beet, spring wheat, timothy and clover grasses, barley, potatoes, maize. Apples, peaches.
Nevada	2.9	Lower valley of the Humboldt and Carson Rivers. Valley of Walker River. N.E. corner of the State in the basin of the South and East Fork.	Prairie grasses, alfalfa, spring wheat, timothy and clover grasses, potatoes.
New Mexico	2.8	Valleys of the head waters of the San Juan, Grande and Canadian Rivers. Rio Grande and Rio Pecos Valleys.	Alfalfa, corn, spring and winter wheat, oats, cotton. Apples, grapes, peaches, pears, plums and prunes, cherries.
Arizona	2.4	Region round Phoenix and Yuma on the Salt and Colorado Rivers.	Cotton, alfalfa, winter wheat, barley, forage grasses.
PACIFIC STATES:			
Washington	2.8	Cascade tributaries of the Columbia River. Okanagan and Upper Spokane Basins. Snake River and tributaries.	Alfalfa, spring wheat, grasses and grains for hay, corn, winter wheat, potatoes, oats, timothy and clover grasses. Apples, ¹ pears, peaches.

¹ The premier crop of the irrigated area of the State is the apple crop for Washington and the orange crop for California.

THE THIRSTY EARTH

	% of Area Irrigated in 1919.	Main Irrigated Areas	Main Irrigated Crops
PACIFIC STATES—(continued):			
Oregon	5.1	Western tributaries of Snake and southern tributaries of the Columbia Rivers, and the Lake Region.	Alfalfa, timothy and clover grasses, prairie grasses, spring wheat. Apples, pears, peaches, plums and prunes, grapes, cherries.
California	21.9	Grand Valley. Lowland round Los Angeles. Imperial Valley.	Alfalfa, hay grasses, vegetables, rough rice, cotton, sugar-beet. Oranges, peaches, grapes, apricots, lemons, apples. ¹

This reclamation of the desert and semi-desert of the Far West is naturally the most important thing that can be said about such districts, but the magnitude of the sums expended and of the masonry erected, the mere enumeration of the thousands of miles of irrigation canals with their cement lining and vast extensions of distributing ditches is a little likely to lead the enthusiast astray. It is said that the territory under the Department of the Reclamation Service has had so far but a small effect upon the trend of national population, and that in the two decades previous to the Census Report the total increase of population in the eight Mountain and three Pacific States was below two millions, a figure low in comparison with the vast size of the land, and, moreover, dependent upon other forms of occupation beside agriculture. Even so, on account of soil and particular difficulties in some areas there can only be increase

¹ See footnote, page 155.

of crop growing by intensive cultivation. It is improbable that much of the arid West will ever be of great agricultural value.

NOTE ON THE REMOVAL OF ALKALI

When the ground water of a field to be cultivated is found to be contaminated with alkali, the injurious element may sometimes be removed by the following device. The field is inundated with good water and thoroughly soaked, after which draining is effected by the digging of suitable ditches. In this way the buried alkali is 'washed out.'

BIBLIOGRAPHY

- FOURTEENTH CENSUS REPORT (U.S.A., 1920): *Irrigation and Drainage* (Vol. VII).
- HANDBOOKS OF THE BUREAU OF RECLAMATION, U.S.A., for 1925-6.
- I. C. RUSSELL: *Geology and Water Resources of the Snake River Plains of Idaho* (United States Geological Survey).
- L. R. FREEMAN: *The Colorado River* (Heinemann).
- I. BOWMAN: *The New World* (Harrap).
- E. HUNTINGTON AND S. W. CUSHING: *Principles of Human Geography* (Chapman and Hall).
- LL. RODWELL JONES AND P. W. BRYAN: *North America* (Methuen).
- J. RUSSELL SMITH: *North America* (G. Bell & Sons).
- GEOGRAPHICAL JOURNAL (Vol. LIV, No. 4, October, 1919): *Irrigation in the United States*.
- GEOGRAPHICAL JOURNAL (Vol. LXIV, No. 6, December, 1924): *Columbia Basin Irrigation Project*.
- GEOGRAPHICAL JOURNAL (Vol. LXVI, No. 5, November, 1925): *The Salt Lake Oasis, Utah*.

CHAPTER XV

NORTH AMERICA

CANADA—THE GREAT LONE LAND

IRRIGATION in Canada has many features in common with that of the United States. There is a somewhat similar continental climate east of the Rocky Mountains, and a similar system of protected valleys among the ranges of the higher land. In addition there is the same problem of 'alkali spots,' and the need, or at any rate the advantage, of 'fixing' nitrogen in the soil by alfalfa growth. But Canada is in more temperate latitudes and the summer heat is not so great, while spring rains are heavier. Moreover the great plains of Canada contain much 'buffalo' grass, a plant once the food for countless herds of bison whose manure, as well as the humus or vegetable soil derived from the grass upon its decay, has left a legacy of fertile nitrogen compounds in a region where atmospheric moisture has been insufficient to leach them out. The ground, too, is largely composed of a rich loam which will stand many consecutive years of cropping.

The irrigable district of North-western Canada lies mainly between Calgary and Medicine Hat, and in the vicinity of Lethbridge. The chief 'project' for the conservation of water is under the control of the Canadian Pacific Railway Company, which holds much land in the neighbourhood of the line. Other Irrigation Companies are the Alberta Railway and Irrigation Company, the Canada Land and Irrigation Company, etc., but irrigation is also undertaken by associations of farmers and even by individuals who have

obtained licence to use the water. The organization of the irrigation is under the immediate authority of the Irrigation Districts Act and an Irrigation Council which supervises the practical details.

The water is the property of the Dominion Government, and permission to use it for irrigation cannot be obtained until the Government has been assured that the conditions are suitable. Notice must first be given stating the height of the land and the source of the water available. The Government experts examine the plan and consult the records, which show the amount of low water the streams have contained for several years previously. These statistics permit calculation of the quantity that can be abstracted for irrigation without detriment to the future supply, or to the supply of others using the stream lower down. A certain minimum must always be left in the rivers so utilized.

The sale of the water is conducted on the lines of a regular tariff: "one cubic foot per second for every 200 acres flowing continuously during the irrigating season," which extends from May 1st to October 1st.

The Canadian Pacific Railway Irrigation Block, in the Province of Alberta, is one of the largest individual irrigation projects on the continent of America. Here the country slopes north-eastwards from the mountains, and once a head of water is obtained irrigation by gravity is easily effected; the water has only to be diverted to flow through the distributing ditches to the 'fields.'

The Canadian Pacific Railway Irrigation Block is worked in three sections—known respectively as the Eastern, Western, and Central, which latter is really highland, and non-irrigable under the present scheme. The Central is, therefore, devoted to cattle pasturage and consequently serves to provide manure for the fields.

To irrigate the Eastern Section water is diverted from the Bow River by a dam built 3 miles from Bassano. This gives a head of water 40 feet above the normal level. The

Bassano Dam has steel and concrete gates and is operated by electricity. The main canal taking off from the dam carries the water 5 miles and then forms a reservoir from which two secondary canals lead it away to supply 2500 miles of irrigation ditches. This same dam also feeds the artificial 'Lake Newell,' another irrigating reservoir, a few miles from the town of Brooks. This 'lake' holds sufficient water to cover 185,000 acres to a depth of one foot.

The Western Section of the C.P.R. Irrigation Block is in a district lying 150 miles south-east of Calgary, and between the Bow and Red Deer Rivers. The main line of the C.P.R. runs along it. By soil and relief it is eminently suited for irrigation, the water being diverted from the glacier-fed Bow River, which has floods in June, July, and August, but not in spring. Its extent is estimated at 218,980 acres, of which 49,752 only were irrigated in 1922.

Water for this Section is diverted from the Bow River at Calgary. Here it is admitted by concrete head-gates into the main canal, a structure sixty feet wide and one in depth. A subsidiary canal holds water for use in an exceptionally dry season. Three secondary canals draw upon the main one, and bearing it through a total length of 246 miles, supply 1113 miles of distributing ditches.

The C.P.R. takes the water to the highest point on the boundary of the farmer's land: he must thereafter manage his own ditches for himself. The water is given free, but the farmer pays the C.P.R. one and a quarter dollars per acre per year for the upkeep of the system, the payment not beginning until a year after the date of the contract. Good irrigated land is about fifty dollars an acre. The Company also supplies trees to the settlers, in order that they may have shade for their homesteads and garden plots of small fruit. The quantity of clay in the sandy soil makes it hold the water very well, so that frequent irrigation is not required.



C.P.R.

THE BASSANO DAM, BOW RIVER, ALBERTA

This dam supplies the Eastern Section of the Canadian Pacific Railway Irrigation Block.

The two Sections of the Canadian Pacific Irrigation Block contain 618,980¹ acres of irrigable land, spread over a much larger extent, of which in 1921 and 1922 only 122,000 and 143,127 respectively were irrigated.²

South of the district just mentioned lies the Lethbridge Block. It was originally developed by the Alberta Railway and Irrigation Company and is the earliest of the large irrigation projects in the Province. In 1912 this block became the property of the Canadian Pacific Railway Company. The water is drawn from the St. Mary River, fed by glaciers and snows of the Rocky Mountains, with some supplies from the Belly and Milk Rivers. This is the greatest alfalfa-producing section of Western Canada. Out of a possible 77,162 acres of irrigable land belonging to the Alberta Railway Company, 72,845 acres are already under cultivation.³

Another section of the Bow River is held by the Canada Land and Irrigation Company: construction here is in progress and 9809 out of a possible 202,640 acres are at present developed. This is but a small portion of the irrigable land held by this company,⁴ but there is some rainfall which may lower the ratio of *irrigated* to *cultivated* acres from year to year.

Besides wheat, which yields 19.5 to as much as 40 or 60 bushels per acre according to locality, the irrigated products include sweet corn, cucumbers, squashes, cantaloups, water-melons, tomatoes,⁵ nearly all of which are fruits of great desirability in an arid land. Other crops are alfalfa, field peas, brome⁶ and timothy grasses, sugar-beet, barley,

¹ Sessional Papers, 1924, 1925.

² From figures given in the Annual Report of the Department of the Interior, 1923; Sessional Papers, 1924.

³ Sessional Papers, 1924.

⁴ Acres irrigated by the Canada Land and Irrigation Company in 1922: Sessional Papers, 1924.

⁵ Sessional Papers, 1924.

⁶ Not, of course, the weed variety.

vegetables, flax, etc. There is a large market for the produce of Alberta in the mining and lumbering districts of British Columbia.

This south-west corner of Alberta still holds out considerable prospects, especially in the district of Lethbridge. Other enterprises have been initiated of which one, the Taber Irrigation District, is already beginning to make its way. Certain parts of the Province of Saskatchewan might also be profitably irrigated with water from the North Saskatchewan, Clearwater and Red Deer Rivers. A number of schemes are already contemplated and all this new land would take spring wheat.

Maps dealing with the survey and population of the country and the government reports show how large is the territory awaiting development, and intending settlers may easily be misled by the cheapness of this 'empty' land. Already it has become necessary to sound a warning note. Successful farming in western Canada can only be achieved "by careful cultivation of every acre." Non-success is partly due to the inexperience of many of the emigrants and partly to the high price of the necessary irrigation works.

The true significance of the irrigation in progress and in anticipation in north-western Canada can only be estimated when the tentative nature of its beginnings are taken into account. No Government revenue is recorded as arising from this source until 1896, when the receipts only amounted to about £20 (98 dollars), though the year 1900-1901 showed a threefold increase.¹ This step forward appears to be almost entirely due to the opening out of new wheat lands, Canadian production rising from 56,000,000 bushels in 1900 to 400,000,000 bushels in 1922.² The wheat crops are regarded as the salvation of the Dominion, and what they have meant to Canada cannot be more emphatically expressed than in the words of the Report.³ "Among

¹ Actually 313 dollars (Sessional Papers).

² *Natural Resources of Canada* (Department of the Interior).

Canadian field crops wheat stands first. . . . Wheat has been the most powerful factor in attracting population and capital to the Dominion, in bringing virgin areas under cultivation, in widening the market for domestic manufacturing, mining and other industries, in building up the volume and value of export trade, and in creating the purchasing power necessary to finance Canada's heavy imports of textiles, iron and steel, sugar, coal and other essentials which, for various reasons, are drawn wholly or largely from abroad. . . ."

The second development of irrigation in Canada is in British Columbia. In this province much of the agricultural land lies in long valleys shut in by high mountain ranges running transversely to the rain-bearing winds from the sea. Moisture thus condenses upon the westward slopes of the coast ranges, or upon the upper levels of the more inland, but higher mountains, so that these intermont valleys with some exceptions are generally free from rain. What precipitation there is, is usually less than 13 inches per year, while the tendency to a winter maximum renders the climate somewhat 'Mediterranean,' which even with great rainfall requires irrigation for summer crops. On the other hand, numberless rivers roll down the mountain slopes, though the fact that the height of the ground above the streams, the consequence of river-erosion in a dry country, renders irrigation difficult has very much curtailed the cultivable area. Here irrigation requires co-operation in labour and a large expenditure of capital. Unirrigated, the land does not produce its best, and may even be completely sterile.

The irrigated districts lie in those provinces of British Columbia known as the Kootenays and the Southern Interior. This latter locality was formerly devoted to cattle ranching, and some years ago Lord Aberdeen established the celebrated Coldstream Ranch in the Okanagan Valley. The ranches have been replaced by fruit farms, combined with some dairy farming. Apple orchard keeping

was begun in 1892, but Okanagan apples did not reach the London market until 1903. Apple growing is the premier fruit industry.

A Joint Stock Company controls the irrigated lands; reservoirs and ditches are being constructed to enlarge the existing schemes and a rent is charged for the use of the water. The holdings are of ten acres and upwards.

Apart from these private enterprises there are some extensively irrigated areas still to be purchased or leased from the Government. They are mainly situated in the southern end of the Okanagan Valley, and here a nursery has been established "at which trees and plants acclimated to the district may be obtained."

Among the irrigated fodder crops are red clover, brome and timothy grasses, and alfalfa, which latter in some instances is harvested three times a year. In addition to apples, tree fruit consists of pears, plums, apricots and cherries. There are also strawberries and a special reputation has been established for all varieties of small bush fruit such as raspberries, blackberries, loganberries, gooseberries, and currants. It is noteworthy that in 1891 there were 6500 acres under fruit, whereas the figure has now risen to 40,000 acres.

BIBLIOGRAPHY

- SESSIONAL PAPERS OF THE PARLIAMENT OF CANADA : 1902, 1924, 1925.
NATURAL RESOURCES OF CANADA : *Department of the Interior* (Ottawa, 1923).
LL. RODWELL JONES AND P. W. BRYAN : *North America* (Methuen).
G. CHISHOLM : *Commercial Geography* (Longmans).
CANADIAN OFFICE : Reports and Booklets, 1924, 1925.
OXFORD SURVEY OF THE BRITISH EMPIRE. *America* (Clarendon Press).

CHAPTER XVI

LATIN AMERICA

MEXICO AND THE HIGH ANDES

WE saw in a previous chapter that the great arid Plateau of Mexico consists of ranges of deeply folded mountains whose enormous valleys have been buried under the stupendous outpourings of lava and the débris from the denuded crests of the folds. We saw, in addition, that the inland drainage resulting from the position of its bounding heights had given rise to a number of 'hydrographic entities' or basins in which a considerable amount of agriculture was possible.

The methods of irrigation in Mexico are still primitive, though good crops are obtained. The long, tree-shaded irrigation ditches, brimming with water, provide for maize, sugar cane, wheat, alfalfa, and beans, which latter makes one of the staple products of the Mexican diet. Apples, pears, peaches, and grapes also are extensively cultivated.

The irrigation in operation in this thirsty land now, as of yore, requires co-operation in labour if ditches are to be dug and irrigation plant installed. Hence there is still the 'community unit' coincident with the 'irrigation unit,' and in their methods of farming, no less than in their ancestry, the Pueblo people of the present day are the descendants of those of the time of Cortez.

Of recent years there has been a great step forward in respect to the production of irrigated cotton. Some mention has already been made of the Mexican connection with the Imperial Valley Industry, with United States control of the

dual area. On the Plateau itself the chief cotton-growing district is found in the northern inland drainage basin, which is watered principally by the Rio Nazas, sometimes fancifully called the Mexican Nile. Actually this basin has many analogies with the celebrated oasis of the Old World, though of course there are striking differences. One of these consists in a rainfall which, occurring in short, tempestuous outbursts, produces surging floods during which much silt is spread over the inundated areas.

The Rios Nazas and de Nieves rise among the eastern slopes of the Western Sierra Madre, in the States of Durango and Zacatecas respectively. Their waters in general disappear far out on the floor of the arid basin, but in storm time a spate 10 to 15 feet deep and 300-500 feet wide comes down the River Nazas, widely overflowing the banks of its lower course, and eventually emptying itself into Lake Parras. This lake represents the remains of a once vast inland sea whose desiccated bed, now covered with lacustrine deposits, is the celebrated 'Laguna,' the premier cotton-growing district in Mexico. Though normally the water of the Nazas is extensively utilized for irrigation, that of the flooded stream is very largely useless. After the manner of the Nile at Aswân, it is proposed to erect a barrier at some convenient gorge in the river's course. The water of the Laguna, which is said to be "worth its weight in silver," has been the cause of bitter strife and feuds among the various cotton-planters. The propensity to divert one's neighbour's water to one's own crops brought down the interference of the Mexican Government and certain laws concerning water-rights and usage were promulgated. The cotton mills of this district are worked partly by the hydro-electric power derived from the streams that rise on the western slopes of the Eastern Sierra Madre.

Though irrigation in Mexico is still carried out by means of primitive ditches and harrowing, there are certain 'projects' on foot to extend the methods of the United

States into that country. Already, near El Paso, the Rio Grande project receiving the storage water from the Elephant Butte Reservoir in New Mexico has become international as well as interstate and supplies water to 25,000 acres in the Republic of Mexico (Bur. of Rec., 1926).

The irrigation operations of South America fall roughly into a threefold classification. They may be described as belonging to the 'alluvial fan and basin,' the 'desert oasis,' and the 'temperate lowland' systems of artificial watering.

The region of the alluvial fan and basin irrigation is that of the Central Andes. With certain variations two main ranges respectively named the Eastern and Western Cordillera span the Pacific side of the Continent. In Peru they are separated by a central ridge which in the absence of transverse river gaps acts as a complete barrier to the moisture-laden winds which blow upon the eastern, or montana, slopes. In Bolivia the central ridge broadens out to become that high plateau which ranks among the most lofty and extensive plateau regions in the world. South of Bolivia the ranges draw near together again, becoming at once narrower and lower. About latitude 42° S. (the northern limit of cool-temperate Chile) the Western Cordillera disappears, or may be represented by that archipelago of islands which are the summits of the peaks of the submerged mountain chain. In these latitudes a constant wet wind blows inland from the west coast, and the single remaining range has been worn through, allowing some rain to get to the Plateau of Patagonia in its lee, though the amount is by no means great.

All the year round Peru and Bolivia are in the trade wind latitudes, and the winds are more or less parallel to the coast (blowing counter-clockwise round a high pressure centre in the Pacific), so that the rainfall is very small or non-existent as in the Atacama Desert and the arid coast lands to its north. Any winds reaching these tracts from the east, however originally laden with moisture from the

sea or the gigantic river swamps of the tropical interior of the continent, are drained first by the bordering heights to the east. But whereas Chile and north-west Argentine have a 'Peruvian' climate down to latitude 30° S., between 30° and 40° S. Chile has a dry 'Peruvian' summer (November to April), and a rainy winter (May to October). The climate of this middle section of Chile is therefore of the Mediterranean type.

The Atacama Desert rises behind the low coastal range. Sandy plains give place farther eastward to mountainous ridges enclosing saline lagoons and dry, salt basins. The higher ground has a general elevation of 7000 to 13,500 feet. Thus the water supply of this region comes from the melting snows which have fallen upon the peaks and ridges of the high Andean Chain.

The mountain zone of the Central Andes, whether they be in Peru, northern Chile, or north-west Argentine, has certain dominant features. Beneath the snow-line are high tracts of grassland or rugged country seamed with narrow, tributary valleys down which speed snow-fed torrents carrying vast quantities of rock waste to the lower intermont basins. The high-Alpine pasture ends naturally in patches of woodland, below which is a second and gently sloping pasture irrigated by canals from the streams for fodder crops, maize, barley, and vegetables.

The lower pasture ends abruptly and the tributaries have now to traverse cañon country to reach the main valley or basin. When they arrive their pace is checked and deposition of the coarser part of their load takes place. In this way an alluvial fan is built up, with coarser silt at the head, the deposit becoming finer and finer as the fan pushes across the valley. The basin floor eventually becomes covered with this rich alluvium, and both it and the subsidiary fans are cultivated by the method of terrace irrigation.

The variety in the crops grown necessarily depends upon the altitude, for all the basins are formed in much the same

way, though a gathering stream in one may become a tributary stream lower down. The distinguishing factor is temperature, here chiefly dependent upon height above sea-level.

An elevation of 10,000 to 11,000 feet serves for wheat and barley in the irrigated basin near Cuzco in Peru. In the basins of the Eastern Cordillera of the Argentine barley is grown at 9000 feet and potatoes at higher altitudes. Fodder is also extensively produced to meet the requirements of the droves of cattle and mules used for the transmontane trade with the nitrate towns of Atacama.

The basin of Abancay, which lies south-west of Cuzco, is much lower, so that tropical and subtropical fruits and sugar are cultivated. The basins of Peru are exceedingly prosperous. Sugar is also a notable crop in the Salta Basin of the north-west Argentine. Frequently there is simple pasture on the coarse alluvium at the head of the tributary fans, thus allowing mixed farming.

The Plateau of Bolivia receives thunder rains at the change of the seasons as well as light showers at other times. These provide for some natural pasture, but food crops require irrigation, here difficult to carry out, owing to the rugged nature of the surface. The water, drawn from snow-fed streams, is guided among precipitous cliffs on a journey frequently extending three to four miles. It is carried sometimes in trenches, sometimes in small aqueducts, sometimes in little tunnels, until a suitable level space or terrace is reached where a small 'field' can be laid out and cultivated.

Westward from the high rim of the plateau, the ground drops away in gorges and basins of the kind already described, terminating in a piedmont slope very promising for agriculture as far as the soil is concerned, for it is built up of the finest waste of the weathered heights. All the fans in the descent are cultivated in terraces and here also the nature of the cultivation depends upon height, that is,

upon temperature. Above 14,000 feet there is only bleak pasture: at 11,000 feet there are irrigated potato fields, and it is a matter of interest that the potato, a form of food which we should find it difficult to replace, appears to be native to these Andean highlands.

Lower fans are planted in succession with orchards and vineyards, sweet peas, oranges, and also violets, hyacinths, and other flowers. At every halt, barley is grown upon the coarser alluvium.

The piedmont slope contains 50 per cent. of the entire agricultural population of Bolivia outside the department of La Paz, and these agricultural communities are becoming wealthy because of the marketing facilities afforded to their barley, vegetables, meat, and blankets in the ever expanding and neighbouring mining settlements.

The northern section of the Argentine Andes are cut longitudinally by a series of rectangular gullies and basins separated from each other by steep-sided mountain ranges, and the same formations are also found upon the edge of the Argentine Plains. They are designated *valles*, though their origin is tectonic and not due to stream erosion. Such are the Lerma Valle, the Valle d'Uspallata, etc., and, in fact, the Central Valley of Chile. With the exception of this last, more fertile than the others, their interest lies in the oasis character of their cultivation. Streams totally out of proportion to their extent lead down into and across them, frequently disappearing by evaporation and leaving their tale of salt. Where the entire waters of the streams have soaked underground they can be made to surrender much of these buried supplies by means of trenches dug in the wet sands. When the trenches are full the water is led to the bank of the water course and carefully distributed. After the need of the crops has been supplied, drains carry off the unused liquid and return it to the river bed.

Santa Maria in the Province of Catamarca is an oasis

created in this way, but south of Tinogasta, at Sauces, in the Province of La Rioja, the process is repeated at every bend in the course along an extent of 50 miles.

After the water has been lifted to the levels of the fields bordering the banks, trenches paved with rounded pebbles lead it into 'oasis-gardens,' where each cultivator raises the crops he requires for the use of his family. A fierce wind of the chinook variety, here called the *zonda*, blows into the basins, and the oases are accordingly sheltered with poplar trees. Sometimes the oasis is natural, and not created, the stream which has disappeared in the gravelly fringe of the *valle* reappearing on the basin floor. Everywhere vine is grown and, at the foot of the vine, alfalfa.

The Great Valley of Chile occupies the section of this country regarded as 'Mediterranean.' It is a very long and narrow groove of tectonic origin. Being protected by the coastal range from the wet west winds of winter, it can only be cultivated when watered artificially from mountain streams. Agriculturally, this Valley is the richest part of the Republic, its products being the usual fruits and cereals grown in the similarly tectonic and climatic Valley of California. The crops are therefore those of the Mediterranean natural region: wheat, maize, barley, warm temperate fruits including the vine, and tobacco.

BIBLIOGRAPHY

LL. RODWELL JONES AND P. W. BRYAN: *North America* (Methuen)

C. R. ENOCK: *Mexico* (T. Fisher Unwin).

C. R. ENOCK: *Peru* (T. Fisher Unwin).

J. BRUNNES: *Human Geography* (Rand McNally).

PIERRE DENIS: *The Argentine Republic* (T. Fisher Unwin).

CHAPTER XVII

SOUTH AMERICA

LOWLANDS WEST AND EAST¹

THE temperate lowlands on the eastern side of the Andes and the coastal plains of Peru and Chile fall into a class slightly differing from that in which must be placed the territory of Latin America considered in the last chapter. In the case of portions of the coastlands of Peru and Chile extensive development of irrigated agriculture, whether in progress or anticipation, is the work of foreign firms and undertaken for purposes outside the general sphere of South American life. In the case of the Argentine the character of the products obtained and their associated industries differentiate the area from the typical South American Republics.

It has been seen that the climate of these lowlands west of the Andes is practically rainless, though north and south of Atacama there is some natural watering by means of the *garuas* or 'sea mists' which creep inland at nightfall and at sunrise or in winter, and which are sometimes of great agricultural value.

The Atacama Desert repeats in climate and partly in soil the features of the Sahara; it also repeats the oasis method of agriculture. The streams from the Western Cordillera are lost beneath the sandy surface long before they reach the sea. Small villages subsisting on the products of their pasture and irrigated agriculture have

¹ These lowlands are, of course, part of 'Latin America,' but for certain reasons they have been grouped apart.

grown up upon the river banks and the gravelly patches where the water disappears. Beyond lies the desert with its oases now producing date palms and thus providing halting-places across the waste of sand. Long ago they supplied food, water, and men to the Imperial armies of the Incas, making possible the conquest of the land to the south.

In the northern part of the desert the oases are cultivated by the mountain shepherds, who practise here a species of transhumance¹ similar to that customary in the Alpine regions of Europe. Frequently the entire population consists of shepherd families whose men-folk spend the winter upon the oasis and retire to their mountain pastures for the rest of the year. During this absence the women and the aged till and tend the crops among which is fodder (alfalfa), a somewhat unusual feature of oasis-cultivation.

In the more northern part of the Desert, life is becoming progressively less primitive, for the produce of the labour goes to feed the nitrate settlements, thereby inducing through contact an influx of ideas and overseas commodities.

North of the Atacama Desert lie the arid coastlands of Peru. They occupy a strip of territory 1400 miles in length and of varying width not exceeding 90 miles. The rainfall is never greater than two inches a year, and may be less, and the *garuas* furnish the bulk of the precipitation. The strip is crossed by some fifty torrential streams originating in the rain and snows of the Andes to the east, though in certain localities these streams may dry up wholly in summer. All of them are in request for irrigation, but owing to lack of modern barrages much of the water is lost for agricultural use. This region, therefore, holds out great possibilities, for only about 3 per cent of the cultivable area is irrigated. The

¹ The term is best explained by an example taken from the dairy industry of Switzerland. The cattle are kept on the high-Alp pasture during the summer and in the lower valleys during the winter. The herd-tenders and the cheese-makers must have two homes, the summer and winter barn or chalet.

largest 'project' is on the River Quiros (Chira), which is tapped by a canal 34 miles long. There is also some artesian water.

The high temperature provides for sugar, cotton, rice, and maize. Sugar is the premier crop and the British Cane Sugar Company has a large concern here, manufacturing rum, which is sold in Bolivia. The labour employed is mainly Japanese, because the Peruvian workman has the habit of ceasing to work for others at certain seasons in order that he may cultivate his own little crops, a practice perhaps inherited from Inca times.

One of the four kinds of cotton grown in Peru is of a special character, for unlike the more usual form of cotton fibre, this variety is somewhat rough and will therefore combine with thread of another calibre, e.g. wool. The principal production, however, is of the native and the Egyptian varieties. The excessive fertility and the climate will sometimes allow two crops a year. The rice, too, is excellent and is much grown for local use.

Irrigation in the Argentine to the lee of the Andes has not as yet received its greatest possible development. The irrigable area falls approximately into a twofold division with, however, considerable overlapping.

The first section is in the west of the country, the piedmont of the Andean slope, where the *zonda* rages furiously and the soil contains much coarse sand and gravel. The chief towns,¹ Mendoza, San Juan, Tucuman, Salta, and Jujuy, sufficiently determine its position, which comprises their provinces. Here there is very little rain but plenty of water from the Andean streams, which, however, would be more effective did not the *zonda* dry up the springs and irrigation ditches. The natural vegetation is scrub, and there are lakes and pools, marshes and swamps, where the mountain streams terminate on the sandy levels. This is the consequence of the character of the soil deposits,

¹ Really oases, though Tucuman is less so.



A. H. W.

THE QUIROS VALLEY, PERU
Before irrigation.



A. H. W.

THE QUIROS VALLEY, PERU
After irrigation.

which are vast accumulations of alluvial material flung down by former river systems much more extensive than at present. The accumulation takes the customary form of alluvial fans or 'dejection' cones. The summits of the cones are coarse gravel, while lower the deposits become progressively more finely grained. The water courses crossing them lose considerably by seepage, and the underground water so provided comes to the surface at the base of the cone, causing the swamps and marshes already mentioned. The vine is cultivated half-way up the sides, the gravel of the summits being too coarse and the bases too wet. The roots are irrigated in a novel and ingenious manner. Drainage trenches are cut in the surface and the amount of the underground water is so regulated that it can feed them.

Viticulture is the staple in the oases of Mendoza, San Juan, and San Rafaël. The atmosphere is so dry that after maturity the harvest can be left without injury on the vine for as much as two months. Thus there is no rush to gather in the crops and the difficulties arising from the employment of 'migrating' harvesters is avoided. The quality of the grapes, with their somewhat excessive amount of sugar and low amount of acid, prevents fermentation taking place without exterior aid, and the great expense of this operation falls upon the actual wine manufacturers. The two branches of the industry are therefore kept quite distinct, the grape-grower providing the fruit but otherwise taking no part in the enterprise. This specialization tends to promote a good quality in the product, particularly as the wine manufacturers use the best European apparatus.

The sugar industry of Tucuman, farther north, possesses points of special interest. At no time a domestic industry, from its earliest days it was carried on with the aid of an expensive irrigation installation. Thus the production was in the hands of a few rich owners, with traditions of the best methods, both in the cultivation of the cane and in

sugar refining. Since 1897 the Public Works erected by the Provincial Authorities have brought good water within the reach of every farmer.

The region of the Gran Chaco (Great Chase or Hunting-Ground) is mainly in the Argentine. Lying still nearer the equator than Tucuman, the Chaco raises successful cotton crops. The estates are held by Europeans, but the labour is Indian and the methods of production are rather primitive.

The second section of the irrigable area of the Argentine lowlands is the 'Physiographic Pampa.' This is a natural region of grassland once, according to tradition, covered by sea. Gravel and sand derived from the waste of the Andes have been spread out over the floor, the finest sediment accumulating in the east, so that even pebbles are absent from the sand or loamy soil. This latter factor, together with the remarkable uniformity of the surface, makes the eastern pampa uniquely suitable for ploughing and the usual agricultural operations. The piedmont sand and gravel, the fine character of the rest of the lowland soil, recall the Ganges Plain and the analogy is strengthened by the vast amount of underground water. This water has in part been extracted from the rains on the montana slopes of the Andes, and has worked its way eastward to the subsoil of the Pampas; in part it is the accumulation of rain-water which throughout long periods has fallen upon and soaked into the porous soil, collecting in the undulations of the old palæozoic (permian) floor. In the more southerly portions of the country the gaps in the Andean Chain are low, and the wet winds penetrate them. Still, obviously this amount of rainfall will be limited.

The true pampas are celebrated for cereals, with wheat, barley, oats, and alfalfa as irrigated crops. These are extensively raised in the provinces of Buenos Aires, Santa Fé, Entre Rios, Córdoba, and the Pampa southward to the neighbourhood of the Rio Negro. The low-lying levels of

the pampas in this part of the country have given to the Argentine abundant harvests and the result has been a world trade putting its productions definitely outside the category of the customary South American exports. Here are the great wheat fields with a rainfall that would appear sufficient, but which can, in times of drought, be supplemented by wells. The land between the Colorado and the Negro Rivers is especially wheat producing, though it is also irrigated for peaches and apricots; it is anticipated that in quality and quantity these fruits will rival ultimately the similar products of California. Orchards are also to be found in the north-east provinces of the country, especially upon the delta of the Parana with its annual deposition of silt following upon an annual flooding. Here, in addition to the apricots and peaches just mentioned, pears, apples, figs, quince, etc., thrive on the rich alluvium.

Perhaps a word should be said upon one very serious drawback to agriculture in north and central Argentine. This is the locust pest. No mere figures could give any adequate understanding of the intensity of the locusts' invading hosts. It is said that the cloud of insects measures fifty to sixty miles across, and that their passage continues without intermission for several days. Nevertheless the Commission of Agricultural Defence has this matter in hand, and hopes in time to remove entirely what is really a national misfortune. Meanwhile much in palliation is already being done.

The southern part of the region passes into that shingle desert which is becoming known as the 'shingle steppe.' Here, by irrigation from mountain streams, alfalfa is raised for the cattle industry.

The relatively cool climate of the Argentine makes the country very suitable for European immigration, and in effect fully 50 per cent of the population is Italian by immigration and descent. The Italian in the New World shows himself to be sober, industrious, and frugal, all of which qualities make for success. The crops raised are not

only necessities with a clamouring world-market, but easily handled. However, the agriculturists are faced with certain disadvantages. At present the use of the wells for the recovery of the underground water is rather potential than actual, and in times of drought the effects are extremely disastrous in the Argentine as in the Deccan. The immigrant Italian is faced with additional drawbacks. The land is actually in the hands of large estate-owners and the immigrant labourer works on the basis of a three years' tenancy, during which he breaks in the ground by sowing wheat and, in his third and final year, cultivates alfalfa for the owner. Lacking land he cannot undertake the profitable 'large holding' agriculture.

BIBLIOGRAPHY

- C. R. ENOCK : *Peru* (T. Fisher Unwin).
PIERRE DENIS : *The Argentine Republic* (T. Fisher Unwin).
W. H. KEBEL : *The New Argentine* (T. Fisher Unwin).
A. B. MARTINEZ AND M. LEWANDOWSKI : *The Argentine in the Twentieth Century* (T. Fisher Unwin).

CHAPTER XVIII

WHITE AUSTRALIA

IN two respects the Continent of Australia is perhaps unique among all the southern territories now ruled over by the White Man. On the one hand its late discovery and colonization has made it a promising ground upon which to experiment with 'modern methods,' and unhampered by traditions; on the other, the difficulties arising from alien dominance over subject people living upon their native soil have not here arisen, owing to the small numbers of the original inhabitants. This freedom from racial problems is the basic fact underlying the present policy of a 'White Australia,' and is directly due to the scanty natural resources of this singularly arid country.

The Continent was early inhabited, nevertheless, but away from the eastern coastlands the difficulty of gaining a living was so great that those enduring this state of privation were in the highest degree ignorant. The sum total of their knowledge of agriculture was apparently contained in the single truth that if all the edible roots were gathered in one season, the next would be wholly barren. Periods of famine were frequent and to preserve the tribe at all—Nature's great never-ceasing effort—'useless mouths' had to be sacrificed. From the dire necessity of finding a remedy for the superfluous population and of keeping what food there was for the strong or those fitted to preserve the race, arose the seemingly cruel practice of infanticide and murder of the sick and the aged. The dark vices of this luckless people were perhaps almost unavoidable in their dry and thirsty land.

Yet, had the primitive inhabitants but known how to deal with it, the soil was amazingly fertile; and the water was present, even in large quantities, had they but possessed the scientific eyes of the modern well-digger, or the no less useful, if unexplained, qualities of the water-diviner, with which to seek and find it.

In Australia there are the customary sources of water supply: mountain and lowland rivers and underground water. Consequently, according to the position of the cultivable land, irrigation is effected by the three most general methods.

A glance at the relief map of the Commonwealth shows that in general the coastal plain is non-existent or extremely small, the coastal mountains, especially in the east, being much higher than the interior plateau. The seaward slopes of these ranges condense the rains of the landward-blowing winds, which therefore descend upon the interior as dry winds, both on account of their loss of water and the heating effect of their descent. In consequence though copious moisture is deposited upon the mountains, the aridity of the sun-baked interior is very considerably increased.

In the south-east corner of the continent are the lowlands of Queensland, New South Wales, and Victoria. They are crossed by the enormous waterways of the combined Murray-Darling system, with its long and important tributaries. These rivers, rising near the crest of the coastal ranges and sweeping through the gorges of the westward slopes in swift torrents, have not always sufficient water to maintain their lowland course, and are often intermittent.

Much of the heavy, summer rainfall of the coastal ranges ultimately percolates underground, and flowing westward, is held beneath the surface by layers of rock or clay through which the water cannot penetrate. Here and there 'faults' occur in the rock floor, and the water comes to the surface in springs which, though frequently quite warm, are utilized

in a manner similar to the Italian *fontanili*. Extensive borings have proved that this section of the Australian interior is the greatest artesian basin in the world. Its extent may be gauged by the fact that it covers an area nearly five times that of the British Isles.¹

The first permanent settlements made by Europeans in Australia were naturally upon the east coast; Sydney (1788), Hobart (1803), etc., and it was not until 1813 that the inhabitants of the settlement near Sydney were forced on account of an abnormal drought to find some way inland. Crossing the ranges of the Blue Mountains, they discovered great rivers flowing westward, and apparently leading into the heart of an unknown country whose obvious aridity gave no great promise. Many years later (1879) the Government Astronomer of New South Wales came to the conclusion that only 1.46 per cent of the rain falling in its catchment area was discharged by the River Darling, and it was suggested that the residue might have soaked down under the porous soil. Whether this explanation be correct in whole or in part is a matter open to discussion, but it led to successful well-digging in the west of New South Wales and in Victoria, and to the first attempts to recover for surface use the vast supply of underground water which undoubtedly exists in this region.

In 1882 the Government Geologist of Queensland came to the conclusion that there was great promise of artesian water in west Queensland, and three years later the Blackall Bore, 1663 feet in depth, released a buried reservoir whose water rose to the surface and flowed at a rate of nearly 300,000 gallons (or nearly 48,000 cubic feet) a day. This success was eagerly followed up, and in June, 1904, about a thousand such wells were under contribution, one of which, the Whitewood Well at Bimerah, was no less than 5046 feet deep.

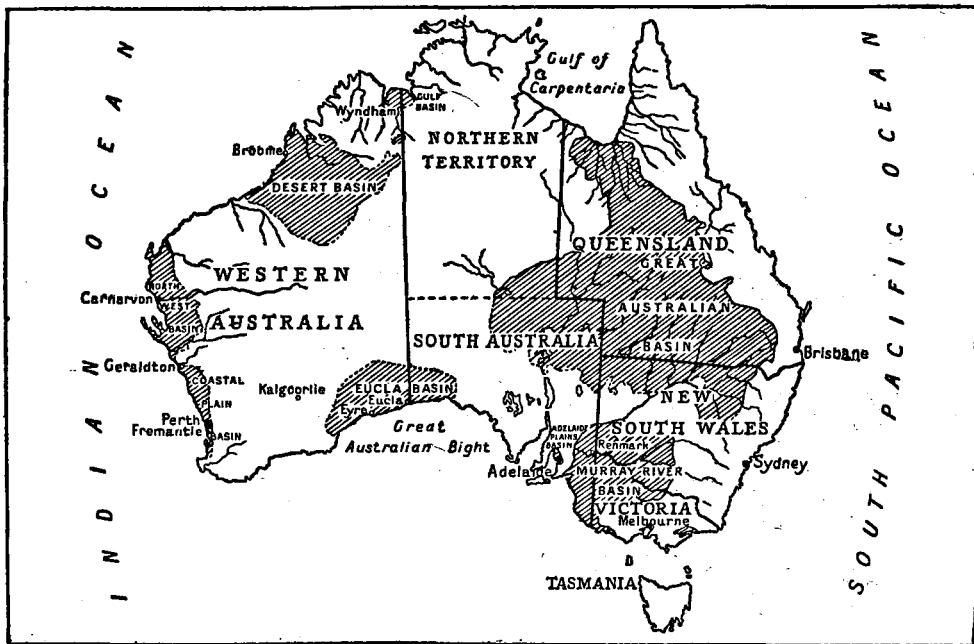
¹ Divided among the States thus : Queensland, 376,000 square miles; South Australia, 118,000 square miles ; New South Wales, 80,000 square miles ; and Northern Territory, 25,000 square miles (1925 *Year Book*).

A considerable amount of well water is now obtained in Queensland, New South Wales and Victoria, the method of its recovery being that in customary use for this kind of supply. When the wells are sunk the water rises to the surface of its own accord, or is pumped up if the hydrostatic pressure upon it be insufficient. In either case a strong pipe and tap control the issuing fluid, which is passed into trenches and used to water cattle. The keeping of herds is made possible by a light rainfall which serves for some natural pasture. Owing to its brackish nature artesian water in Australia is rarely used for irrigation though a little lucerne is grown by its help. Its salinity, chiefly due to sodium carbonate, is explained as a result of the great depth from which it rises, for the shallower bores in America and India bring up water very suitable for plant growth.¹ It is invaluable, however, in keeping open the stock routes across the arid lands. In recent years the discovery of artesian water at Maffra, in Victoria, has led to the successful growing of the sugar beet in that district.²

The various artesian bores differ in certain characteristics. In southern Queensland there are three from which water flows for a distance aggregating 148 miles. The water, which rises from a depth of nearly 3000 feet, is at boiling-point when it reaches the surface. In the western plains of New South Wales and in the Riverina District, water is obtained from shallow or 'sub'-artesian bores. They are as yet few in number, but appear to indicate possibilities for tapping artesian sources not yet investigated. Once raised, windmills and oil engines control the distribution. These sub-artesian wells are generally fresh and fit for human use. Lastly, a new kind of bore has been sunk, tapping other supplies. A tube is made to pass through

¹ An instance of this occurs in some of the very deep wells of the Dakotas, where the water is too saline for irrigation. (J. W. Gregory: *The Dead Heart of Australia*.)

² Victoria League Pamphlets. *Australia*.



THE ARTESIAN BASINS OF AUSTRALIA

numerous layers of salty water beneath which is a stratum quite good for stock. The overlying brine is warmer, and therefore less dense than the underlying, less brackish stratum—a phenomenon not unknown elsewhere. Well-sinking has also been successfully begun in South and Western Australia and the Northern Territory.

As Professor Gregory points out, the origin of this so-called artesian water is open to dispute. The wells may be really artesian in the original meaning of the word, and their flowing due to hydrostatic pressure exerted in some far distant locality. On the other hand, the pressure required to liberate the underground supplies when tapped may be found directly in the overlying rocks. It is possible that some of the water at any rate is 'plutonic,' that is, derived from the interior of the earth by other means than the mere soaking through of far-distant rainfall (meteoric water), and in this case, though very great, the amount would not be inexhaustible. Indeed, even supposing its origin be rain or snow on the Dividing Ranges, it is very likely that the vast accumulation which makes it possible to recover it in useful quantities has in reality been collecting through long periods of time, so that the present rainfall contribution may be insufficient to replace what is being used. If these latter theories be correct, reckless waste of the water may be in the long run highly disastrous, and even extensive use may consume the whole supply.

In addition to the Great Australian Basin just considered there are five smaller artesian basins in the territory of Western Australia. They are known respectively as the Eucla, Coastal Plain, North-west, Desert, and Gulf Basins. The first of these is in the south-east corner of the State, extending also into South Australia. The water is only suitable for stock. The Coastal Plain Basin is in the south-west, extending from Cape Leeuwin to Dongara, and thus includes Fremantle and Perth. In the southern part of this Basin the wells are fresh and supply the town of Perth,

etc., for domestic purposes, but further north the water again becomes saline. The North-west or Carnarvon Basin lies between the Murchison and Ashburton Rivers. The country is said to be ideal for sheep rearing, and the configuration is such that the recovered water flows, by gravitation, for many miles. The Gulf Basin lies at the extreme north-eastern corner of the State, between the Cambridge Gulf and Queen's Channel; so far it has been but little developed. The Desert Basin, or Broome Area, has by far the largest surface extent, with the Fitzroy and De Grey Rivers for its north and south boundaries. This basin also is still awaiting development, but it supplies domestic uses in the town of Broome where three bores, out of the eight for the area, have been sunk.

In the south-east corner of Australia is the Murray River Basin, but whereas some of the water is artesian, by far the greater part of that used on the farms is obtained directly from the Murray River and its tributaries. In this way abundant supplies are ensured, not only for stock but for the cultivation of many kinds of crops.

A little to the east of the junction of the Darling and Murray Rivers lies the township of Mildura, and with the founding of this town Australian Irrigation in the wider sense may be said to have begun. The case of Mildura has the additional interest of providing an example of the method of establishing a new town in a 'new' country.

It was in the late 'eighties that the two brothers W. B. and G. Chaffey obtained from the Australian Government permission to enter and occupy 250,000 acres of land along the Murray River in the Colony of Victoria. Among the conditions laid down by the authorities was one regulating the quantity of water which might be taken from the stream, for example, 30,000 cubic feet per minute in January, 40,000 in June, 60,000 in each of the months of September, October, and November, etc., giving an equivalent rainfall over the

district to be irrigated of 24 inches per year. At the same time at Psyche Bend a magnificent *billabong* was locked after having been filled with flood water for use in such an emergency as failure of the Murray waters, such failure being estimated to occur once in fifty years. The Chaffey brothers entered upon their estate in 1887.¹ This estate bordered the river for 40 miles and stretched back from it for 20. Much of the ground was flat and generally covered with mallee scrub, but contained also some splendid forests of red gum trees and open groves of 'blue bush.'

"It had been a hard time in the mallee country," a certain Francis Myers wrote in 1893, describing this territory before it had experienced the magic touch of water, "and the rabbits had marvellously increased; grass there was none; miserable sheep were dying all around; the parched stranger on the weary horse riding through the country heard nothing but the dry rustle of the mallee leaves, saw nothing but the dull glistening foliage, the red sand driving, the starved sheep perishing, the rabbits skipping about (sustaining life in some incomprehensible manner), and the innumerable ants. The dingo howled by night, the villain crow creaked dismally by day, and the only tolerable spot in the broad acres of hopelessness and misery was the little irrigated garden at the homestead on the river."

The price given for the land was £1 per acre for 200,000 acres—rather excessive, one would think, for estate admittedly desert—but the purchase carried with it "water-rights in perpetual easement."

"The work of reclamation was begun in 1888. First a block of 25,000 acres was surveyed and enclosed with a rabbit- and vermin-proof fence of matting and barbed wire." Taking the landing-place as centre of operations these

¹ Messrs. Chaffey had been largely instrumental in founding an irrigation colony in California, and thither they returned when the Mildura Colony was in full swing. George Chaffey is heard of later in connection with the Imperial Valley Scheme. (See page 148.)

optimists 'surveyed' a township with avenues, town allotments (155 feet by 33 feet), villa lots beyond these, $2\frac{1}{2}$ acres each, and still further beyond, horticultural land allotments of 10 acres each, to be individually reached by an irrigation canal intended to touch the allotment at its highest corner.

Pumping stations were then chosen along the river's course, whence the water might be lifted to channelled ridges commanding the surrounding country, and from these elevated trenches the water was led off in concreted 'creeks,' brooks, and rivulets to supply irrigation ditches. It could now, at will, be made to trickle over the whole surface of the 25,000 acres. For crops the ground was flooded, but for fruit trees the water was held back in furrows.

The promoters of the scheme had hardly begun their operations when storekeepers, butchers, and bakers hurried to the scene, though by an arrangement with the Government of Victoria public houses were rigorously excluded. Settlers flocked readily to the spot, and in a year from the time when the Chaffey surveyor planted his first red flag there were more than five hundred men busily employed upon the irrigation and building operations. In addition a newspaper had been started, aptly entitled *The Cultivator*, and hundreds of bullocks and horses "were working with the plough and scoop in the big channels."

Before planting could be begun the soil had to be prepared. It bore normally little other than stunted eucalyptus, and was in the infertile condition described as 'gum sick.' But among its constituents were free lime and gypsum in abundance, and consequently it was more especially suited for fruit trees, though other crops were likely to flourish. Steam 'cultivators' were put into use for pulverizing the hard, sun-baked soil to a depth of 18 inches.

Two years later the Chaffey Brothers' Estate became the Chaffey Brothers Limited, and the Mildura Irrigation Company was formed. Mildura became a town, "with solidly built, ample offices; with a stately red brick mansion for

Mr. W. B. Chaffey."¹ By 1890 the foundations of the Agricultural College were laid, a post office erected, and "the Wesleyans had built a church and the Anglicans were considering a similar undertaking."¹ A coffee palace, boarding houses, stores, and shops soon made their appearance, and "matrimonial business increased at an unprecedented rate."

The first fruit trees planted were vine and olive. By 1893 vine growths of fourteen months were already giving good results and apricots and peaches of equal age likewise in fruit; wine was expected to be a staple. A wolf-cry of an invasion of locusts was ridiculed, "but," writes the enthusiastic Myers, "an invasion of schoolmarms is much more serious."

Since this time, after overcoming certain unexpected difficulties,² the Mildura Irrigation Scheme has continued to prosper, and according to the latest reports, during the year 1921-22, one particular 30-acre orchard yielded a profit of £2700.

Lower down the Murray River and just across the border of Victoria in the Colony of South Australia, lies the township of Renmark. The Irrigation Trust of Renmark was established in 1893 on similar lines to that of Mildura, but upon a smaller scale. In both districts the fruit grown belongs to that of the usual Mediterranean type: fresh grapes and grapes for drying (sultanas, currants, raisins), and wine, oranges, lemons, apples, apricots, peaches, pears, plums, and olives (for oil). It is noteworthy that not one of these fruits is indigenous.

Contemporaneous with the pioneer settlement at Mildura is the River Goulburn Irrigation Scheme, the largest project of the kind in Victoria. The Goulburn Weir, near Nagambie, was begun in 1887 and completed in 1891. Water is thus diverted eastward and westward into two main canals,

¹ Curtailed from Francis Myers, 1893 (*Irrigation; or The New Australia*).

² Unconnected with either soil or climate.

the first feeding the Shepparton Irrigation district, and the second, carrying an amount more than five times as great, supplying the eastern half of the Rodney main channels, the principal storage basin of the scheme known as the Waranga Reservoir. This latter has been artificially constructed out of a natural depression. Begun in 1902 and completed in 1905, the height of the embankment has been more recently raised to meet the requirements of the extension of the original scheme. The length of the canals, channels, and distributing ditches is now about 1800 miles. The irrigated territory is crossed by the Rivers Goulburn, Campaspe, and Loddon, the water being carried over the Campaspe in a siphon. There is an annual rainfall of 18 inches, but lands under intense culture have water-rights of one acre-foot for every irrigable acre. Ordinary irrigated land has one-fourth or one-fifth of this quantity, according to locality, while holdings not subject to compulsory irrigation may buy water on application for occasional irrigation. The water also provides for domestic and stock supply. The packing of dried fruits, stock-raising and dairy farming are important industries.

By the Water Act of 1905 all local control in the irrigated districts of Victoria was abolished, except in the case of Mildura, which is still administered under the authority of the First Mildura Irrigation Trust. The cost of irrigation head-works on the Goulburn, Loddon, and Murray Rivers is now borne by the State. A further vigorous policy has resulted in a movement for a 'closer settlement' in the irrigated districts. To effect this the State reserves the right of purchasing irrigated lands even when already in occupation and re-selling to settlers under what are known as 'closer settlement' conditions. To facilitate this sale the State offers liberal terms and advances in money and stock, and in return the settler and his successors are bound to reside on the irrigation block for at least eight months in each year. When the blocks were first thrown open for purchase

the State, if desired, constructed the plant necessary for watering a portion of the holdings, graded soil and seed, and gave assistance and advice generally through their experts, so that cultivation should begin under the most profitable auspices. The cost of this was to be recovered by a system of instalments extending over ten years, and the scheme has proved so successful that the State has already been fully recompensed.¹

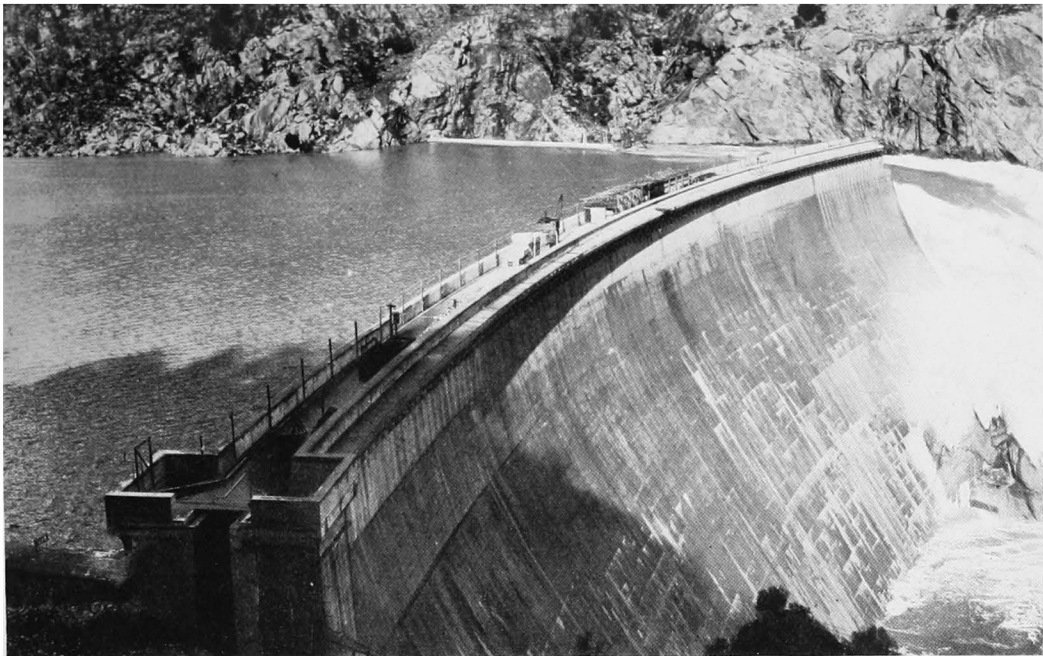
During and after the European War of 1914-18 arrangements were entered into by the State Authorities for irrigation blocks to be taken up by discharged soldiers, and in 1920 out of 540 blocks granted in Victoria to new settlers 529 of them were given to such soldiers, the gifts including houses as well as land.

The rains of the Murray catchment area are uncertain, and care has to be taken that the water withdrawn for irrigation does not deplete the stream below the navigation depth. This has necessitated the construction of some very large dams, such as the Hume Dam, begun on November 28th, 1919, which will take rank as the fifth largest water storage at present in existence. When completed the reservoir will be 47 miles long, in places 3 to 4 miles wide, and of a uniform depth of 60 feet.

Another of these monster dams is the Burrinjuck Reservoir, also called the Burren Juck or the Barren Jack. It is on the Murrumbidgee tributary of the River Murray, in a hilly district near the site of the new federal capital, Canberra. The masonry is 240 feet high, and closes a narrow gully between red granite mountains. It is said to hold back sufficient water to cover Hampstead Heath to a depth of a quarter of a mile. A more precise estimate is 33,612,671,000 cubic feet of water.² The water is not

¹ With the exception of the Northern Territory, the Closer Settlement Policy has been adopted in all the States of the Commonwealth. Among them, however, there are some differences in the conditions of purchase and compulsory residence.

² *Australian Year Book*, 1915. The figure given in the Victoria League Pamphlet (33,000,000) is an obvious misprint.



Australian Commonwealth

THE BURRINJUCK DAM ON THE MURRUMBIDGEE RIVER, N.S.W.
The dam holds back 33,612,671,000 cubic feet of water, or nearly 800,000 acre-feet.

diverted at the dam, but released as required along the course of the river. The controlled stretch of water is 240 miles. The take-off is effected by horizontal canals, and as the river is all the while descending to lower levels these canals are naturally higher than the country to be irrigated. The minor channels and distributing ditches can therefore be filled by gravity. At Narrandera a diversion weir provides for the irrigation of the Yanco and Griffith districts, and flourishing settlements have already sprung up in the neighbourhood of the first. In the Griffith district a "viticultural nursery has been established for the propagation of vines on phylloxera resistant stock."

In this way over 200,000 acres will ultimately be watered, and wheat, vine, vegetables, fruit, and lucerne (this last for the use of cattle in times of drought), are the typical crops. The Murrumbidgee River Scheme includes the establishment of towns and villages with roadways to serve each farm. Farmers to the numbers of 2070 are already settled upon 190,610 irrigated acres.¹ The crops are of the previously mentioned varieties.

It is proposed to spend £10,000,000 on additional works upon the Murray, works which when completed will transform what is not a very inviting piece of country into one of the foremost among the productive regions of the world.

A characteristic of Australian Irrigation is the length of the growing season and the wide choice of industries. Victoria farms of 60 acres usually devote 20 to 30 to fruit and vines, 20 to lucerne, and the remainder to dairying. With care the lucerne crops may be harvested six times a year, producing six tons of hay to the acre. This lucerne serves to fatten sheep and lambs for the market.

The size of an average fruit and vine farm is from 10 to 30 acres, but when in addition dairy cattle are kept the holdings are between 50 to 100 acres.

The fruit farming industry is well organized, drying and

¹ Statistics for 1925.

canning being undertaken in co-operative factories. This corner of Australia is widely advertised as one of 'the lands of opportunity' attractive to emigrants, who may choose the crops they prefer and rely upon the sunshine and the water for an unfailingly splendid harvest. The export trade is mainly in apples, oranges, pears, and grapes, and the Commonwealth claims to command the highest prices of all the apples which are sent to Britain.¹ Irrespective of the export of flour, which is appreciable, in 1923, 12,000,000 bushels more of wheat were exported than in 1910.

This short account of the present and anticipated agricultural development in south-east Australia will serve to show how very far irrigation in Victoria has progressed from the simple beginnings of the Chaffey Brothers' Estate at Mildura about forty years ago. Irrigation works on an extensive scale have so far been almost entirely confined to the Murray River Basin, but there are attempts in other directions. Western Australia with its enormous proportion of desert land is, of course, less open to irrigated agriculture, but still there are small tracts bordering the rivers of the south-west upon which, when irrigated, fruit, fodder, and potatoes are grown. These are private schemes, but a Government undertaking at Harvey provides for the irrigation of 4000 acres devoted to fruit growing, chiefly oranges. This latter scheme, opened in 1916, is in process of enlargement. It is unlikely, however, that development will ever proceed very far in this country where almost every geographical factor seems so unpropitious.

In Queensland some shallow-well irrigation is supplemented by a small enterprise with channels and ditches on the River Burnett. Here, as at Mildura, pumping machines lift the water to the level of the main canal. The venture is extremely limited.

¹ Statistics for 1925.

NEW ZEALAND

The peculiar aridity of Australia does not extend to New Zealand, where the climate is essentially temperate, with an average rainfall of about 50 inches. Central Otago, which lies in a rain shadow, is very dry, and here irrigation has been attempted. The water of the streams crossing it is diverted in a simple manner and serves 60,000 acres which are planted with English grasses and orchards. This grassland allows of five sheep to an acre, while apricots, peaches and other temperate fruits attain great perfection. The almost virgin soil is remarkably fertile and a scheme is under consideration to reclaim by irrigation another 232,000 acres. Expert opinion has stated that "marvellous results" are to be expected.

Farther north and east in the Canterbury Plains there is a great promise of artesian water which, except close to the sea coast, is quite fresh. At present it is used for stock and domestic purposes only, but owing to its position in a 'rain shadow' this part of the country has periods of heat and drought and the artesian water may be used for agriculture at some future time.

NOTE ON THE ORIGIN OF THE WATER IN THE
GREAT AUSTRALIAN BASIN

Plutonic water may exist as a constituent of the buried magmatic material which comes to the surface during volcanic eruptions, or it may have been captured and held in the ancient rocks during their sedimentation, or be occluded in the quartz crystals of granites and become liberated upon distintegration of that quartz into sand.

Professor Gregory regards the water of the 'Dead Heart' of Australia as plutonic. He bases his conclusions on its frequently high temperature, which may reach 212° F., the nature of its salinity, and on the apparent preservation of

its 'hydrostatic head,' which if the water really originated in far-distant Queensland, ought to be reduced considerably in the centre of the Basin by the friction of the water in passing through the interstices between the sand grains. The pressure of the overlying rocks and the gas pressure due to the internal heat of the earth would be sufficient to make the water rise in the bores, and hence the phenomena of the 'flowing wells' need not be explained on the basis of an artesian theory.

This hypothesis has been fiercely contested, notably by E. F. Pittman, formerly Government Geologist of New South Wales. He quotes similar anomalies of pressure in the undoubted artesian wells of Kentucky and Paris, denies Gregory's statement that the salinity of the wells decreases from east to west, and places no credit in the theory of a pressure supplied by overlying rock or heated gas. Professor Gregory was at one time connected with the University of Melbourne, so that he may be said to have studied the matter on the spot, but even if the water be really artesian there are grounds for believing the amount, though enormous, to be limited (see page 184).

BIBLIOGRAPHY

- J. W. GREGORY, F.R.S., D.Sc. : *The Dead Heart of Australia* (John Murray).
- OXFORD SURVEY OF THE BRITISH EMPIRE : *Australasia* (Clarendon Press).
- F. MYERS : *Irrigation ; or, The New Australia* (1893). (Printed for Chaffey Bros., Mildura and London.)
- COMMONWEALTH OF AUSTRALIA : Official Year Books (1901-12, 1913, 1914, 1915, 1916, 1920, 1921, 1924, 1925, 1926).
- STATE RIVERS AND WATER SUPPLY COMMISSION, VICTORIA : *Sixteenth Annual Report*, 1920-21.
- VICTORIA LEAGUE PAMPHLETS : *Australia*.
- COMMONWEALTH OF AUSTRALIA : Miscellaneous Pamphlets, 1925.
- DOMINION OF NEW ZEALAND : Pamphlets, 1925.

CHAPTER XIX

BRITISH SOUTH AFRICA

THE term British South Africa includes territory which is politically outside the Union of South Africa, but in this chapter attention will be confined to the Union itself, South-west Africa (former German West Africa) and Southern Rhodesia. All of these countries possess one or more of the types of climate that usually pass under the name of Mediterranean, Desert, Scrub or Semi-Desert, so that it is obvious that British South Africa should lend itself to irrigated agriculture.

THE UNION OF SOUTH AFRICA

In the Union of South Africa the climate expected from considerations of latitude and size are greatly modified by the configuration of the country. It is an ancient plateau block rising very abruptly from the coast; the customary coastal plain is here extremely small. In addition, the climate is affected, at any rate near the sea-board, by two currents of water which flow the one up the western, and the other down the eastern sides of this part of the continent. The first of these streams is the Benguela Current, whose surface waters are cold in comparison with the latitude, so that winds blowing inward from it are likewise cool; and since the capacity of air to absorb moisture decreases considerably with decreasing temperature, these winds are likewise dry. When they have mounted the higher rim of the plateau they drop upon the slightly lower interior surface, becoming warmed in their descent. These winds are now both warm and dry and therefore more ready to

absorb than to give out moisture. In consequence of this the coastland of South Africa from the Olifants River in the Cape Province to Loanda, far beyond the northern limit of our region, is an almost rainless tract.

The effects of the southwards-flowing Mozambique Current on the east coast are exactly the reverse. Warm, wet winds blow landwards from it carrying rain not only to the south and east, but also to the interior.

The south-west corner of the Cape Province gets the major portion of its rain in winter, from the then prevailing north-west winds, while the summers are dry and hot. Elsewhere, except for a little strip along the south coast, the rain falls at the season of the greatest heat, increasing eastward it is true, but not being very regular. Moreover, the rain in the interior is of the thunderstorm variety, torrential while it lasts, not striking deep into the parched ground, but carrying away large quantities of the surface soil. The storm over, intense evaporation reabsorbs much of the water that has fallen. Clearly the summer rains are not of high, general value, and for good cultivation must be supplemented by irrigation.

In spring, too, when both summer and winter crops need moisture except in the extreme east, where there is rainfall at all seasons, the scant and unreliable rainfall necessitates irrigation. Only in a few districts sufficiently near to the Drakensberg Range to get spring rains and in a small region round Cape Town can wheat be grown without artificial watering.

But with all this crying need for irrigation there are certain facts that bring out the contrast between South Africa and the Argentine or the Murray River Basin of Australia. To begin with, the soil of South Africa as a whole is infertile, and only in certain river valleys can deep, rich loams be found. The country is a plateau of very ancient rock, long subjected to the agents of destruction, and the rock waste which in other cases goes to make a good soil has been

carried away and deposited upon the ocean floor. In certain places it is present, but in the condition known as 'brak.' By this is meant that it contains a sufficient quantity of soluble salts to injure the plants, and these salts may also occur in streams which would otherwise be of utility for irrigation. Overwatering, here as in the New World, may result in the formation of infertile 'alkali spots.' Lastly, there is the fact that a plateau block like South Africa, with its interior heights not greatly elevated above the general surface, cannot have the same abundant sources of water as are met with elsewhere.

Sir William Willcocks has reported that the dolomitic limestone region from the River Vaal to the latitude of Pretoria in the Transvaal is riddled with caves and caverns in which underground water collects to be ultimately discharged in perennial springs. These latter are frequently of sufficient size to supply not only present needs but future requirements should the land be opened up for the irrigation of cornfields, fruit orchards, and tobacco plantations. He considers that 500,000 acres in the high lying tracts, and double this number in the lower ground, are capable of being advantageously irrigated. Otherwise, the nature of the surface in a dolomite country is not propitious for cultivation.

It is obvious that the irrigable area of the Union is limited. It has been estimated that only 2 per cent. of the surface can ever be profitably cultivated, and that of this not more than 4,000,000 acres (6250 square miles) could actually be irrigated. At present the irrigated land is assessed at 572,003 acres.¹

The irrigable areas are mostly in the south-west of the Cape Province, where the alluvial soils of the Breede, Sunday, Fish, and other rivers give good crops. This is equally true in the valley of the Orange River, but here development is awaited. In the Transvaal the scanty summer rain, the infertile, brak soil, favour only a coarse and

¹ Statistics from *Geographical Journal* (Vol. LXV, No. 4, April, 1925).

tufted grass which sustains pastoral industries, though irrigated oats at times provide for supplementary fodder and hay.

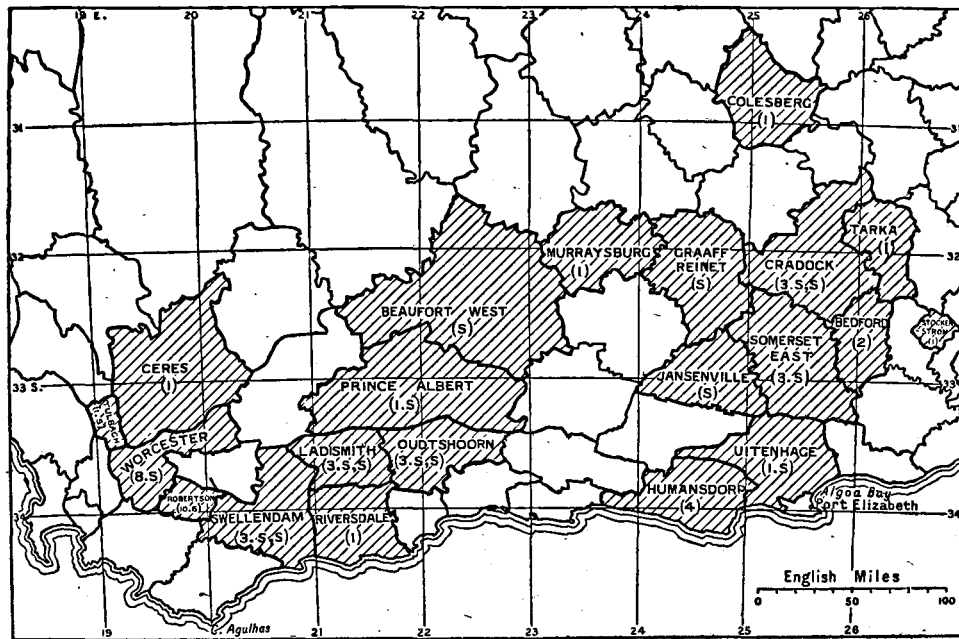
In Natal there are two irrigation settlements, neither of very large extent. The first and chief is the Weenen Irrigation Settlement on Bushman's River in Thorn Country, a name sufficiently explicit. Here there are fertile soils of volcanic and alluvial origin, and in winter the splash of green of the irrigated crops is in striking contrast to the browns of the surrounding desert. Half of the cultivated area (2043 acres) is under lucerne, which grows luxuriantly and can be harvested seven times a year. The annual value per acre of the crop when utilized for ordinary purposes is £15, but when used for ostrich farming, an industry recently started, the value is increased to £50.

The second settlement is at Winterton. The soil here is very poor, and the small irrigated holdings raise food for the winter use of dairy cattle. There is a sufficiency of natural pasturage to tide over the summer.

Previous to 1915 irrigation in those parts of the country now forming the Union of South Africa was of an elementary character. It consisted of shallow well borings,¹ and the simple diversion of streams, but as a diversion could only be effected during floods, this source of irrigation was somewhat unreliable. On account of the small number of waterings it requires the chief crop raised was lucerne. In the Karroo the annual flooding is generally enough, but in the more arid part of the Cape Province where floods are few, the flinging up of low dams across wide and flat valleys allowed for the basin form of irrigation.

Though 1915 marks the development of a more scientific form of irrigation, the Government interest did not wait so long. In the Cape of Good Hope, previous to 1906, the water-rights were based upon the Roman Dutch Law,

¹ Between 1903-25, 9884 bores have been sunk by the Boring Branch of the Irrigation Department.



IRRIGATION IN THE CAPE PROVINCE, SOUTH AFRICA

The districts of Kimberley and Kenhart have been omitted

(For key to this Map, see page 202, footnote).

which had resulted in the creation of complicated rights regarding the use of the streams. The outcome of this confusion has been a more or less selfish use of the water without any regard for the reasonable requirements of others. Irrigation was of practically no importance except in the Oudtshoorn District of the Cape Province. Here, however, has grown up a richly irrigated area in the Little Karroo containing fields of lucerne entirely devoted to ostrich farming—for which purpose, indeed, lucerne seems to have been first extensively cultivated in South Africa.

In 1906 an Irrigation Act, and again in 1908 the Transvaal Act, were passed, dealing mainly with the administration of the law in connection therewith, but after the Union (1910), the matter was taken in hand more thoroughly, and in 1912 the Union 'Irrigation and Conservation of Waters Act' was passed. This Act provided for a national law regulating the use of water in public streams, defined water-rights, and made provision for the settlement of disputes. In addition an "Irrigation Loan Department" was organized, that monetary assistance might be given to private individuals and such Irrigation Boards as required it. An Irrigation Department, with a Director of Irrigation at its head, was created to deal with the administration of the Act.

The method of applying for the right to use a stream or spring water for irrigation is somewhat as follows: Any three 'riparian' owners can petition the Minister for the formation of an Irrigation District, and if the owners of not less than two-thirds of the total irrigable area to be served by the scheme are in favour, the Governor-General-in-Council proclaims the Irrigation District constituted. All the irrigable land in the district then comes under the authority of the Board for rating purposes.

Between 1906 and 1915 there was a rapid extension of flood irrigation in the Cape Province; the schemes were small and inexpensive, the object being fodder and grazing. The replacement of flooding by storage in certain localities

dates from the Law of 1912. Among such enterprises were those upon the Rivers Breede and Fish, while new schemes connected with the Olifants and Sunday Rivers were inaugurated. There are also great storage works in the Oudtshoorn District of the Cape Province, namely, the Kamanassie Dam at Oudtshoorn and the Nels River Irrigation Works at Calitzdorp in the vicinity. In the Orange Free State the Vaal River Barrage near Vereeniging is of monster dimensions, and great constructions are in progress there and in the Transvaal (Rustenburg, etc.).

By March 31st, 1925, ninety-eight Irrigation Districts had been constituted in the Union, the greater part of whose irrigation has been developed in this way, especially in the Cape Province.

Where there are winter rains the majority of the European cereals can be grown without artificial watering, but it is required in the regions of summer rain. Wheat is not an important crop, because African wheat is liable to 'rust,' and the difficulty of raising it of good quality puts it out of competition with the more easily grown product of other lands. The best irrigated forage crop is lucerne, and the yield of its hay ranges from four to eight tons per acre each season. The ease with which lucerne can be grown accounts for the rapid development of irrigation and the expansion of the live-stock industry. The early connection of this crop with ostrich farming has already been noticed; in 1913 the ostrich feather industry realized £3,000,000. It also plays a noted part in the more recent pig-rearing and beef export trade. Some of the Cape lucerne finds a market in England and in Holland. Dairy farming, too, is very much upon the increase, and lucerne hay is likely to become the most important supplement to veldt grazing.

There is fruit farming in the Breede River basin, oranges requiring autumn and spring irrigation. The Virginian variety of tobacco is grown as an irrigated crop in the Transvaal, and in view of the fact that maize is a staple

food for five millions of natives, quite apart from its value as a cattle food, its cultivation by irrigation might assume importance. The scanty summer rain and brak soil of the High Veldt mark it out for pasture land, but even here, by the help of irrigation, oats are grown for fodder or hay.

The Irrigation Department of the Union of South Africa is somewhat akin to the Reclamation Service of the United States of America, and like that Service, has a department dealing with the practical study of irrigated crops. The Experimental Farm and School at Potchefstroom, in the Transvaal, was opened in 1909. At Groot Fontein, investigations are being carried out upon the injurious or beneficent properties of the storm waters and upon soil-alkali problems.

The Union of South Africa is a vast territory and obviously its agricultural future is mainly bound up with its pasture land and the raising of stock. The 'paradise' that has been predicted in the case of that Land of Opportunity now opening in south-eastern Australia is not to be here expected. Still, much has been done and much will be done and this aspect of the country's resources will take a not ignoble place among the contributing factors that are giving so promising an outlook to this corner of our Empire.¹

¹ The following list gives the names of the Districts in the Cape Province of the Union of South Africa in which there are irrigation works. The figures refer to Works completed by March 31st, 1923, and each letter 'S' to a storage dam completed or authorised by the same date. (Compiled from information given in the latest obtainable *Official Year Book*, No. 7, 1910-1924.)

Beaufort West . . .	S.	-	Oudtshoorn . . .	S.S.	3
Bedford . . .	-	2	Prince Albert . . .	S.	1
Ceres . . .	-	1	Riversdale . . .	-	1
Colesberg . . .	-	1	Robertson . . .	S.	10
Craddock . . .	S.S.	3	Somerset East . . .	S.	3
Graaff Reinet . . .	S.	-	Stockenstrom . . .	-	1
Humansdorp . . .	-	4	Swellendam . . .	S.S.	3
Jansenville . . .	S.	-	Tarka . . .	-	1
Kenhart . . .	-	2	Tulbagh . . .	S.	1
Kimberley . . .	-	1	Uitenhage . . .	S.	1
Ladysmith . . .	S.S.	3	Worcester . . .	S.	8
Murraysburg . . .	-	1			



Union of South Africa

WEIR AND CANAL INTAKE, SUNDAY RIVER VALLEY CAPE PROVINCE

SOUTH-WEST AFRICA

The territory of South-west Africa lies between the Cunene and Orange Rivers. It is an area of great dryness and contains large tracts of desert and scrub. Except along the northern and southern boundaries, which are watered by the Cunene, Okavango, and Orange Rivers, there are no permanent streams. But though the rivers of the interior only flow in the rainy season, water can generally be found a few feet below their beds. There are also artesian bores in the Auob Valley, whose water is released by the modern methods of pipe and stop-tap. Their average depth below the surface is 250 feet and the water is put to stock and domestic use. When the natural rise in the bore is insufficient, the water is pumped to the surface, windmills supplying the motive power.

SOUTHERN RHODESIA

Southern Rhodesia lies between the Zambesi and the Limpopo Rivers, but well inland, so that its eastern border is at least 200 miles from the coast. The eastern portion, or Mashonaland, has a line of distinct heights protecting it still further from seaward influences, while the western portion, or Matabeleland, contains the famous Matopo Hills, but falls away inland to the desert and scrub of the Kalahari.

The country lies within the tropics but its temperature is greatly affected by the altitude. Much of the land is above 4000 feet with distinctly temperate conditions. Southern Rhodesia may therefore be regarded as part of 'White Man's Africa.' The small section below 3000 feet is sub-tropical.

The year is divided into two seasons, the wet and the dry. The first is the summer season, lasting from October till the end of March. The dry or winter season lasts from

May to October, but there are some rains in May and September, though during this latter month the fall is mainly in thunder showers. The rainfall, even when small, is reliable, and in this respect Southern Rhodesia differs from the other 'summer rain' districts of South Africa.

Southern Rhodesia is interesting because it contains traces of a very early irrigation. Indications are found of a long vanished system of agriculture of the terrace type. It has been suggested that South Africa received this method of artificial watering from the Arabs or the Phœnicians.¹ However, if ever the prehistoric *negroes* practised it, it was an art the native races have long forgotten.

The principal area of cultivation is in central Mashonaland, where an average annual rainfall of 25 to 35 inches allows for summer crops, but as stock raising is the main industry diversion irrigation from permanent water courses provides fodder for the dry season. There is also some irrigated fruit culture, especially of oranges, and a little winter wheat, though some of it does not require irrigation. This is also true of tobacco and cotton, for which the natural rain is sufficient.

Matabeleland, further inland, has a lower rainfall and fewer rivers. These latter are employed in irrigation by the process of lifting their water by means of a pumping apparatus into a prepared channel.

So far there have been two water-storing enterprises, the Mazoe Poort Dam and the Matopo Dam. The first of these, on the Mazoe River, has a capacity of 762,000,000 cubic feet and can irrigate 6000 acres. The Rhodes' Matopo Dam impounds 64,000,000 cubic feet of water, and can supply 900 acres, which, however, is considerably in excess of the available land. There are also some less important schemes and at present a total of 10,000 acres is being irrigated.²

¹ Sir H. Johnson: *The Opening up of Africa*.

² 1925 Statistics.

Here, as in the Union, the public streams and waters of the Colony are considered the property of the State, and except for domestic purposes and the use of cattle, water may not be diverted from them for irrigation unless the necessary sanction has been obtained. All legal aspects come under the Water Ordinance of 1913 and the Water Ordinance Amendment Ordinance of 1920, and experts from the Irrigation Branch of the Department of Agriculture make the necessary surveys and investigations and are ready with advice.

BIBLIOGRAPHY

- G. CHISHOLM : *Handbook of Commercial Geography* (Longmans).
OXFORD SURVEY OF THE BRITISH EMPIRE : *Africa* (Clarendon Press).
UNION OF SOUTH AFRICA : *Official Year Book*, No. 4 (1910-20); No. 7 (1910-24).
VICTORIA LEAGUE PAMPHLETS : *The Union of South Africa*.
SOUTH AFRICAN RAILWAYS : *Natal Province* (1911).
GEOGRAPHICAL JOURNAL (Vol. LXV, No. 4, April, 1925) : *Irrigation in South Africa*.
UNION OF SOUTH AFRICA : *Reports of the Irrigation Finance Commission*, 1925, 1926.
COLONY OF SOUTH RHODESIA : *Miscellaneous Papers*.

CONCLUSION

MAN AND THE EARTH

THE foregoing account of the application of artificial watering to the arid lands of the Ancient and Modern Worlds is by no means exhaustive. Our own continent of Europe, for instance, contains certain localities not generally associated with aridity, but which nevertheless display some interesting features of irrigated agriculture, and among them may be placed the Valais, in Switzerland, where glacier-water is diverted into troughs or pipes to supply the 'upper pastures.' In Porto Rico and Hawaii wind-sheltered fields of sugar cane must be irrigated, while irrigation is one of the factors responsible for the progress of British as compared with the French and Dutch Guianas. Aboriginal peoples all over the tropics have long been familiar with the process of irrigation as a means of land cultivation, and an interesting example occurs among the big banana-growing tribes of the Fly River, New Guinea, where the necessity for co-operative irrigation and drainage appears to lie at the base of their political divisions.¹ Similarly in Africa primitive irrigation is a necessary feature of the native agriculture upon the semi-arid plateau of Bechuanaland, the alluvial valleys of Portuguese East Africa, the terraced rice-fields of Madagascar, and the terrace irrigation which occupies the greater part of northern Abyssinia.² But though these peoples and regions are interesting on account of their present interpretation of old-world processes, it is not necessary to discuss

¹ *Unexplored New Guinea* (W. N. Beaver).

² *The Tropics* (C. R. Enock).

them here. Without them, indeed, the story of the thirsty earth has been sufficiently detailed. A few words, however, remain to be said upon the rôles played in the great drama by the co-operating partners—Man and the Earth.

This retrospect of the course of agriculture from its primitive beginnings, through the long centuries of Man's gradually increasing skill, has enabled us to discern the advent of his domination in this as in the other spheres of his progress. The master-mind that has transmuted ores into metals and metals into machines, stones into paints and paints into pictures, vibrations into sounds, and sounds into music, has been no less worthily occupied in this great contest with the adverse forces of climate and soil. For man has planted his fragrant gardens in the heart of the untamed desert, and released from its tomb the rain that fell ere ever our Island was made. He has forced the water to travel uphill, that it might descend like rain upon the lower fields. The raging floods he has secured to his use, and threaded with rivers the dry and thirsty lands.

To these, man's strenuous endeavours, the earth has responded splendidly. She is a great reservoir of fertility, ready at the touch of the cultivator to bring forth her thousand fruits. But to produce of her best she must be carefully tended and fed, and the connection between the words husbandry and husband still possesses its ancient significance.

In some social communities where populations have become congested, the cry is "back to the land." Rather should it be "forward to new lands," lands clean as the unpolluted air that blows across them, lands holding in abundance and primeval purity the promise of un failing harvests.

Long ago great Empires rose and waxed through agriculture, and when their agriculture declined, they, too, became enfeebled and disappeared. To-day the world holds out the same, and yet quite other opportunities. We do not

start, as did the ancient civilizations of the East or West, from rude beginnings, for we have with us the heritage of the ages, with their warnings and examples.

Agriculture bids fair to call to life the unpopulated lands of the New Worlds, and the future may yet reveal a super-Babylon, founded on the ideals of the past, enhanced by the glorious possibilities of the present of which that past never could have dreamt.

BIBLIOGRAPHY

- AUSTRALIA, COMMONWEALTH OF. Official Year Books (1901-26),
Government Reports, Pamphlets, Booklets for 1925.
- BOWMAN, I. *The New World: Studies in Political Geography*
(Ed. 1924).
- BROOKS, C. E. P. *The Evolution of Climate*.
- BRUNHES, J. *Human Geography* (Translation).
„ *L'Irrigation . . . dans la Péninsule ibérique. . . .*
- CANADA: DEPARTMENT OF THE INTERIOR. *Natural Resources of*
Canada (Ottawa, 1923).
- CANADIAN OFFICE, THE. Reports and Handbooks, 1925.
- CHISHOLM, G. *A Handbook of Commercial Geography*.
- CONWAY, SIR MARTIN. *Palestine and Morocco*.
- DENIS, P. *The Argentine Republic* (Translation).
Engineer, The. The Sennar Dam (August 28th, 1925).
- ENOCK, C. R. *Mexico*.
„ *Peru*.
„ *The Tropics*.
- FAIRGRIEVE, J. *Geography and World Power*.
- FREEMAN, L. R. *The Colorado River*.
- FURLONG, C. W. *The Gateway to the Sahara*.
- Geographical Journal*—
Vol. L, No. 5, Nov. 1917. Irrigation in the Dâkhla Oasis.
Vol. LIV, No. 4, Oct. 1919. Irrigation in the United States.

Geographical Journal—

- Vol. LIV, No. 5, Nov. 1919. The Irrigation of the Konia Plain.
- Vol. LVI, No. 2, Aug. 1920. Exploration of Tibesti, Erdi Borku, and Ennedi.
- Vol. LVI, No. 6, Dec. 1920. Across Arabia.
- Vol. LVII, No. 1, Jan. 1921. Modern Exploration in the Oasis of Siwa.
- Vol. LIX, No. 1, Jan. 1922. The Influence of its Geography on the People of the Aurès Massif.
- Vol. LXIII, No. 3, March 1924. Hasa : An Arabian Oasis.
- Vol. LXIV, No. 6, Dec. 1924. Columbia Basin Irrigation Project.
- Vol. LXV, No. 2, Feb. 1925. Irrigation in the Indo-Gangetic Plain.
- Vol. LXV, No. 5, May 1925. Innermost Asia.
- Vol. LXV, No. 6, June 1925. Innermost Asia.
- Vol. LXVI, No. 5, Nov. 1925. The Salt Lake Oasis, Utah.
- Vol. LXVII, No. 3, March. 1926. The Sennar Dam.
- GREGORY, J. W.— *The Dead Heart of Australia.*
- HOGARTH, D. G. *The Penetration of Arabia.*
 „ „ *The Ancient East.*
- HOLDICH, COLONEL SIR T. *India.*
- HOLMES, W. H. *Aboriginal Antiquities.*
- HUNTINGTON, E. *Civilization and Climate.*
 „ *Palestine and its Transformations.*
 „ *The Climatic Factor.*
 „ *The Pulse of Asia.*
- HUNTINGTON, E., AND CUSHING, S. W. *Principles of Human Geography.*

- HUNTINGTON, E., AND OTHERS. *The Evolution of the Earth and its Inhabitants.*
- HUNTINGTON, E., AND VISHER, S. S. *Climatic Changes.*
- JOHNSON, W. H. *Cotton and its Production.*
- JONES, LL. RODWELL, AND BRYAN, P. W. *North America.*
- KEANE, A. H. *Africa* (Vol. I).
- KOEBEL, W. H. *The New Argentine.*
- LITTLE, A. *The Far East.*
- LYDE, L. W. *The Continent of Europe.*
- MARTINEZ, A. B., AND LEWANDOWSKI, M. *The Argentine in the Twentieth Century.*
- MYERS, F. *Irrigation ; or The New Australia.*
- MYRES, J. L. *The Dawn of History.*
- NEWBIGIN, M. I. *The Mediterranean Lands.*
- " *Tillers of the Ground.*
- NEW ZEALAND (DOMINION). *Government Handbooks* (1925).
- OXFORD SURVEY OF THE BRITISH EMPIRE—
- Africa.*
- America.*
- Asia.*
- Australia.*
- PEACE HANDBOOK. *Turkey in Asia.*
- PETRIE, W. M. FLINDERS. *Egypt and Israel.*
- PRESCOTT, W. *The Conquest of Mexico.*
- " *The Conquest of Peru.*
- PUMPPELLY, R., HUNTINGTON, E., AND OTHERS. *Exploration in Turkestan.*

RUSSELL, I. C. *Geology and Water Resources of the Snake River Plains of Idaho.*

SCOTT MONCRIEFF, C. C. *Irrigation in Southern Europe.*

SESSIONAL PAPERS OF THE PARLIAMENT OF CANADA. 1902, 1924, 1925.

SMITH, J. RUSSELL. *North America.*

SOUTH AFRICAN RAILWAYS. Natal Province.

SOUTHERN RHODESIA (COLONY). *Miscellaneous Papers.*

VICTORIA LEAGUE PAMPHLETS—

Australia.

Union of South Africa.

UNION OF SOUTH AFRICA. *Official Year Book*, No. 4 (1910-20), No. 7 (1910-24).

Reports of the Irrigation Finance Commission, 1925, 1926.

UNITED STATES OF AMERICA. *Fourteenth Census Report*. Vol. VII, *Irrigation and Drainage.*

Handbooks of the Bureau of Reclamation for 1925-6.

INDICES

Abbreviations: B. = Basin, D. = District, G. = Gulf, L. = Lake, P. = Plain, Pr. = Province, R. = River, S. = State, V. = Valley.
Wherever available, the spelling of the Place Names is that of the *Times*' Atlas Gazetteer.

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