1856. The price of benzole rose to 20*s*. a gallon in 1860, when aniline was 20*s*. a pound.

Those were empirical days, and Professor Morgan's picture of Dan Dawson illuminates the period. This great Yorkshire personality was born in 1836 to a Huddersfield dyer, and his first 10 lb. of magenta, made in the kitchen-oven, not only realised £100 sterling, but coloured the succeeding loaves of bread. By 1874 he had made a fortune, and elected to study chemistry under Hofmann, whose researches had laid the foundation of his prosperity. Accordingly, in 1875 he proceeded to Berlin, while retaining association with his Yorkshire factories, Messrs. John W. Leitch and Company with the Colne Vale Dye and Chemical Company; and after returning from Germany, lectured for several years on the chemistry of coal-tar products at the Huddersfield Technical College.

Professor Morgan has laid under deep obligation all those to whom the early history and the early chemistry of artificial dye-manufacture appear momentous and engrossing. The dramatic evocation of lovely colours, beneficent drugs and agreeable perfumes from a disgusting waste-product must appeal to all who can savour the contrasts of life, and can appreciate the importance of the seemingly unimportant. In romance and enlightenment this industry remains unrivalled, while Professor Morgan brings both attributes vividly to mind.

Data on Post-Glacial Climatic Changes in North-West India.

By H. de Terra and G. E. Hutchinson.

IN the course of explorations carried out in the Himalayas, in Indian Tibet and the Punjab foothills, we have come across a number of phenomena which throw some light on post-glacial climatic changes. In view of the growing interest which geologists, meteorologists and archæologists have recently shown in this problem, it seemed desirable to present our observations and to give a brief summary of the multiple evidence of subrecent climatic pulsations.

This evidence may conveniently be classified as follows:—

(1) morainic deposits lying in an intermediate position between terminal moraines of the last Pleistocene glaciation and recent moraines of existing glaciers;
(2) terraces connected with post-glacial movements of valley glaciers;
(3) lake terraces or raised beaches indicating high water levels;
(4) data inferred from ancient chronicles and prehistoric monuments;
(5) indirect data from observations on rock engravings, patination, etc.

1. Recent studies on the Pleistocene glaciation in Kashmir, which were carried out by the first author and Mr. T.T. Paterson, show that valley glaciers advanced five times, leaving distinct traces of moraines and glacio-fluvial outwash deposits in the valleys. Previously already Oestreich, and especially Dainelli, had presented proof for a complete Pleistocene glacial cycle in neighbouring areas, but only through recent work has it become possible to correlate the glacial and interglacial deposits of the mountainous tract with fossiliferous (mainly Upper Siwalik) formations in the adjoining foothills. This correlation permits of dating the second Himalayan ice-advance as being of Boulder Conglomerate or Middle Pleistocene age, so that the following third and fourth glaciations would fall into the Upper Pleistocene. The terminal moraines of the fourth glaciation were observed between 7,500 and 8,500 feet above sea-level, and in most cases the corresponding trough was appreciably smaller than the higher trough scooped out by the third glaciers. This feature already indicates a progressive weakening of the climatic changes so far as their intensity is concerned. Moreover the fifth ice advance was so weak, as compared with the fourth, that hardly any distinct new troughs were made, the glaciers having formed small ice tongues which may have looked like recent glaciers in a somewhat advanced position. That this fifth ice advance was appreciably weaker than the fourth, is clearly seen from the high position of the last terminal moraines which lie 500 to 2,000 feet higher than the moraines of the fourth glaciers. Commonly there is one terminal moraine wall, but in a few valleys there are two sets, the highest and latest of which lies only 500 feet below the recent glacier snout.

These observations make one suspect a post-glacial age for the fifth ice advance in

Kashmir. There are, moreover, other signs indicating a post-Pleistocene origin, namely :

(*a*) the fifth (and sixth) terminal moraines are thinner and smaller than any of the older moraines, and therefore resemble recent glacial deposits ;

(*b*) their rock material reflects the formational composition of a small area restricted to the uppermost parts of the valleys ;

(*c*) their state of preservation is distinctly fresher than that of the lower moraines.

These observations permit the conclusion that the fifth glaciation, as compared with the longer periods of the major ice advances, was of rather short duration.

The question arises whether there occurred one or two post-glacial climatic pessima. In the upper Liddar and in the upper Vishav valleys in Kashmir, Paterson and de Terra observed two sets of younger moraine walls below the present glacier snout. Similar conditions were observed by de Terra in Western Tibet on certain glaciers which descend towards the Sumjiling plain, east of the border pass Lanak La. The older terminal moraine here lay 1,500 ft., the younger one only 600 feet, below the glacier. Considering that these glaciers lie in perfectly graded troughs wherein the ice movement is relatively stable (as compared with glaciers in the Karakorum range), it is very probable that the two moraines represent subrecent stages of glacial retreat.

2. In Kashmir, as also in the adjoining foothill region of Poonch, the post-glacial terminal moraines are frequently associated with at least one, rarely two terraces. This terrace is composed of glacio-fluvial outwash material which was deposited during the waning stage of the valley glaciers. Within the sequence of terraces, found along most of the valleys, this terrace is the fifth and lowest, being often not more than 10 feet above the present stream level. Its gravel is banked up against a prominent slope below the fourth terrace which in itself is connected with a retreat stage of the fourth glaciers. Between the two ice advances evidently lies a long period of erosion, separating the last of the Pleistocene glaciations from the first post-glacial pessimum. Significantly enough, this fifth terrace occurs far outside of the glaciated tract, as in the Potwar and Indus valley regions, where it clearly marks a stage of valley filling, due most likely to increased water supply.

3. Evidence for post-glacial climatic changes as presented by raised beaches have been frequently cited by Hedin and other explorers. In an unpublished paper on the ecology and zoogeography of the fishes of Kashmir and Indian Tibet, the second author reports such phenomena at Lake Pangur in Western Tibet as follows :—

"Around the present shore of Pangur Tso (a few miles beyond Shushul in Ladak) there is a series of four low beaches which, lying in graded steps between 4345 m. and the present lake level at 4329 m., cut into the Pleistocene interglacial lake deposits and into the base of the alluvial fans which cover them. Beaches of this kind are very usual around the closed lakes of Indian Tibet. It is highly probable that all the closed basins experienced a period of high levels in the closing stage of the last glacial, when much water, stored as ice, must have run into their basins. While it appears that the highest post-glacial levels represent a stage at which Pangur was isolated from Panggong Tso, it is quite possible that the latter had for a time an outflow into the Tang-tse Valley at this period. But it is by no means safe to assume that all of the high beaches of post-glacial age were formed at a very remote time. It has been shown (de Terra and Hutchinson, 1934) that considerable oscillations of lake level occurred during the 19th century, a period not especially remarkable for the amplitude of its climatic changes. It is therefore highly probable that at other periods in historic and proto-historic times, oscillations of considerable magnitude have occurred."

This possibility should be kept in mind when interpreting the great number of raised beaches to be found on the shores of Lake Panggong, Mitpal and Tso Moriri in Ladak. At Mitpal Tso we observed some 16 beaches of which a greater portion seemed to be cut into old alluvial fans. Their formation is doubtless due to a progressive lowering of the lake level, but this limpies that during each successive stage the lake remained sufficiently stable for a great number of years to allow wave action to erode the shore. It is also possible that the dwindling reservoirs of snow and ice on the surrounding mountains controlled to a certain degree such changes of lake level, thus exerting a retarding influence on an otherwise more rapid process of desiccation. Future observations should therefore concentrate on a detailed study of post-glacial shore deposits in relation to raised beaches

and to the stratigraphy of deep water sediments.

Outside of the Himalayas, in the Salt Range of the North-West Punjab, are a number of lakes which lie in a region famous for its archæological records. One of these is the Son Sakesar Kahar, in the Shapur district, near the town of Naoshera. On its western end this lake is surrounded by a wide belt of salt marshes, bordered by a terrace which is four feet above the present lake level. On this were found the ruined foundations of an ancient temple-like building whose architecture suggests its having been erected during the first half of the first millennium A.D. This site still showed a number of limestone slabs lying in step-like manner on the terrace edge as if a staircase had led from the main hall to a lake shore. At present this lake shore is dry, the lake being half a mile distant from the edge of the terrace. Although the villagers admitted that the lake submerged occasionally a small portion of the salt marshes, none could recall that the water had ever extended to the ruins, where a much travelled path has led, since ancient times, across the lake basin. It is therefore very probable that at that time the lake extended to the edge of the terrace and in still older periods it must have swept the entire terrace, which is made of lake deposits. This highest level is indicated by various beach remnants found a few miles east of the village of Chitta where wave cut cliffs occur 7 feet above the present lake level of Son Sakesar Kahar. As the area belongs to one of the driest regions in North-West India, it is obvious that this raised beach must represent a period of abundant water supply.

Smaller oscillations of climate leading to the formation of beaches have occurred during the 19th century in Indian Tibet, as de Terra and Hutchinson (*Geogr. J.*, 1934) have shown. The water level of Panggong Tso fell during the first half of the century, till in 1869 it was about 5·9 m. below the level in 1932; subsequent to 1869 a rise took place, the present level probably being established some time after 1900. A very low shore line, about three meters below the lowest level of the sixties of the last century, was observed by Godwin Austen. This clearly indicates an ancient dry period.

4. The Tibetan chronicle *La-dvags-rgyal-rabs* (translation by A. H. Francke, *Archaeol. Survey of India, New Imp. Ser.*, Vol. 50, 1926) mentions from the environs of Lhasa that during the reign of Sron-Khri-lde-btsam (755–797 A. D.) floods and good harvests occurred, which would indicate a wet period, as such always correspond with fertile years in Tibet at present. Quite possibly, this humid phase is the same as the one which is recorded by a raised beach in lake Son Sakesar Kahar in the Salt Range.

Of greater interest however is the chronicle of the kings of Kashmir, *Rajatarangini*. According to A. Stein's translation it describes a vast lake which occupied the Kashmir valley. This lake was drained off by a heroic act of Khashiap who cut the mountain barrier with his magic sword, thus draining the lake towards India. One would think that this saga referred to the "Karewa lake" which existed during the Ice Age and in which the lake beds were deposited, which nowadays form the so-called "Karewas" or raised terraces. This can hardly be the case, for the Karewa lake was drained off at the beginning of the second inter-glacial, as recent studies have proved, and no human tradition is known to date back to the middle of the Ice Age. It is much more probable that the Kashmir saga refers to a great and prolonged inundation of prehistoric and post-glacial times. Such explanation is borne out by the following facts:—

(*a*) Temporary increase of water supply still leads to disastrous floods in Kashmir, and the valley is at such time transformed into chains of lakes which may occupy one-quarter of the entire valley floor. The survey maps 43*J*, 12, 13, 15, 16 amply illustrate how easily the flood plain of the Jhelum river can be inundated by heavy rainfall.

(*b*) The rigidly observed rule that ancient historic sites and prehistoric dwellings are always found on the tops of ancient river terraces or isolated hillocks in Kashmir, would indicate that a lake actually existed in the valley, flooding all outlets of subsidiary streams as well as portions of the central valley floor. A megalithic monument near Srinagar (at Burzahom) is found on the edge of the crest of a 110 foot terrace which is made of Karewa lake clays. Nowadays the terrace projects into swampy rice fields; but it is evident that the Neolithic settlers carefully avoided the low ground, which at

that time may easily have been the litoral swamp of an enlarged Dal lake whose present shore line is only some twenty feet below the level of the rice fields. A second Neolithic site at Nuna, in the Sind valley, presents the same picture, the midden lying some seven feet below the surface of a higher terrace which offered safer ground for settlement than the lower valley floor. As the latter is nowadays fully cultivated and settled, it is evident that at some remote time the Neolithic people avoided the valley floor, most probably for reasons of higher stream levels.

Geologically the megalithic sites in Kashmir bear not only traces of a wet period but of a succeeding dry period as well. Both at Burzahom and at Nuna, but especially at the former place, the megalithic settlements lie buried under seven to twelve feet of pottery-bearing yellow or grey silty soil. This soil is unstratified at Burzahom and so porous that it can only be a windblown deposit. Under present climatic conditions dust storms occur in Kashmir, though not as frequently as in the Punjab. A somewhat greater aridity might be required to produce such loess-like deposits. Some of the Karewa and younger terraces in Kashmir are covered by very similar thin loess-loam, and it would seem that these represent the same dry period which succeeded the megalithic culture. The dating of this period depends of course on the archæological analysis of the pottery found. As the oldest pottery underlies the strata with black burnished ware, which is related to the Chalcolithic ceramics of the lower Indus valley, it would seem as if the megalith culture flourished around 3500 to 4000 B.C. This dating should be considered tentative until the pottery has been analysed by the Archæological Survey of India.

In this connection it is, however, interesting that Sir John Marshall (*Mohenjo Daro and the Indus Valley Civilization*, Vol. I, pp. 2–3, London, 1931) and Sir Aurel Stein gave indisputable evidence of heavier rainfall in Baluchistan during the Chalcolithic civilization of *ca.* 3000 B.C. Of the following period Sir John says, "much of the desiccation of Baluchistan must have taken place at some period between the Chalcolithic Period when the population was comparatively dense and settled, and the fourth century B.C., when Alexander the Great made his disastrous march back through the deserts of Gedrosia, and when its condition must have been as parched and barren as it is to-day."

Whatever the causes for this climatic change may have been, it would seem that a wet period persisted in prehistoric times in North-West India which was followed by extensive desiccation. To the latter period, possibly, belongs the post-megalithic soil in Kashmir.

The submerged condition of certain Hindu temples in Kashmir, as at Manasbal and Pandrethan (see Ram Chandra Khak, *Ancient Monuments of Kashmir*, London, 1933) also is indicative of fluctuating water levels in the valley. The foundations of the Manasval temple lie, nowadays, several feet below the level of the neighbouring lake; and Pandrethan also stands below the ground-water level. It is unlikely that the ancient architects selected marsh or litoral swamps for their sites, but dry ground which demanded drier conditions in the valley. The temples date back to the 11th–12th centuries A.D.

Since the early part of the 17th century no very large changes in water levels seem to have occurred in Kashmir, as the shore position of the mooring ghats of some Moghul gardens has been retained.

5. Indirect data from observations on rock engravings, patinations, etc.

Data from certain Tibetan rock engravings were collected by the second author (*l.c.* unpublished) who states that the patination of rock engravings (stupas, ibex, etc.) near Kargil cannot antedate the introduction of Buddhism to the country (8th century). This slight desert varnish must therefore have developed since the early Middle Ages.

At Tang-tse in Eastern Ladak, engravings on patinated granite boulders have been found, from which Hutchinson draws the following inferences:—(1) since early in the present millennium no patination has formed at Tang-tse, (2) the brown desert varnish on the oldest inscriptions antedates the Nestorian engravings, (3) pictures of a species of deer (*Cervus cf. hanglu*) possibly indicates that at some period in the Middle Ages Indian Tibet was damp enough to support richer vegetation than is found there nowadays.

At no place did we observe ochreous patination on recent soils, from which we

conclude that the desert varnish must have formed at a period which possessed a more arid climate than is prevalent in present-day Indian Tibet.

Rock engravings more ancient than either the Kargil or Tang-tse sites, occur below Attock on the Indus and on erratic blocks lying on the higher terraces near Campbellpore (Punjab). Their age is at present still under consideration but in any event they can tentatively be dated as belonging to a period intermediate between the Neolithic and Chalcolithic. These engravings show slight desert varnish which is thinner than the patination found on the native rock. The latter is of no diagnostic value but the patina on the engravings might well belong to a prehistoric dry stage of the post-glacial loess period.

Hutchinson also draws attention to the changes in the altitude limit of agriculture in Ladak (as reported by Francke *op. cit.*, vol. 1). A distinct lowering of this limit has occurred since the time when the "Mons", a pre-Tibetan tribe of the first millennium A.D., cultivated the higher ground. He says, "Although the possibilities of agriculture in this region are limited largely by water-supply and by presence or absence of suitable sites for fields, it is impossible that the present altitudinal limit is set by these factors, seeing that practically the whole of the water-supply of the modern settlements comes from snow and ice on the mountains and local precipitation is probably of negligible importance in agriculture, while level sites are found, notably, near Phobrang, above 4500 m. It is therefore clear that if the limit of agriculture was formerly higher, conditions for ripening the crop, now often cut when partially green, must have once been more favourale. This, like the supposed but unproved extension of the tree line, would seem to point to a drier, warmer period.

In conclusion, the data discussed above may be tabulated as follows :—

POST-GLACIAL CLIMATIC CHANGES IN N.-W. INDIA.

Wet.	5th terminal moraine in Kashmir, Epi-glacial.
—	Assumed dry interval, so far unrecorded.
Wet.	6th terminal moraine in Kashmir, Epi-glacial.
? Dry.	Possibly dry pre-Neolithic patination of Indus boulder at Attock and Campbellpore ?
Wet. *ca.* 4000-2500 B.C.	Megalithic settlements in Kashmir. Rainfall in excess of present precipitation in Baluchistan and Upper Sind.
Dry. ? 2000-300 B.C.	Post-megalithic loessic soil in Kashmir. Desiccation in Baluchistan and North-West India antedating Alexander's campaign.
	Pre-Tibetan Mon period, upward extension of agricltture in the first millennium A.D.
? Wet. 8th century A.D.	Period of floods in Central Tibet.
Dry. 11th-12th century A.D.	Submerged Hindu temples in Kashmir.
? Wet. Middle Ages.	In Western Tibet (Tang-tse) drawing of stag.
Wet. 18th century -early 19th century.	High lake levels on Lake Manasarovar in Tibet.
	High lake levels in Western Tibet.
Dry. Middle of 19th century.	Low lake levels in Western Tibet.
Wet. Early 20th century.	Almost all lakes rising in Western Tibet.

SUGGESTIONS FOR FURTHER STUDIES.

The above discussion shows how meager our present knowledge on post-glacial climatic changes in N.-W. India is ; and we suggest for study, therefore, a number of subjects which, in our opinion, would yield more complete information.

(1) Dendrochronological studies on ancient Deodar trees in the Himalayas and on every kind of wood found in ancient graves. (For instance on pine wood, reported by A. H. Franeke from pre-Tibetan Mon graves at Gya in Ladak.)

(2) Studies on lake sedimentation with special reference to the occurrence of brackish or salt water diatoms, such as have already been reported by Lundquist from the Kashmir lakes. Efficient borings through lake sediments would give interesting results as to alternation of $CaCO_3$ and ferrous sulphide rich gyttja deposits.

(3) Additional pollen analysis of Pleistocene and subrecent sediments such as we

began in the last years (see *Memoirs Connecticut Ac. of Sciences*, New Haven, Conn.)

(4) History of village communities in Western Tibet in relation to agriculture, and position of prehistoric sites in relation to drainage pattern.

(5) Analysis of water in closed lakes and estimates of rate of flow into such lakes.

The Karewas of Kashmir.*

By Birbal Sahni, SC.D., F.G.S., F.R.S.,
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THE well-known fact that the fossil remains of sea animals are found on the crest of the Himalayas frequently conveys to the lay mind a picture of mountain tops submerged in an ocean which rose above those heights. Similarly, lake deposits containing the relics of aquatic plants and animals, if found on the elevated slopes of a mountain, might easily convince the uninitiated that a lake must have once existed at that high level.

That this popular fallacy should have invaded the mind of even a modern scientist is the excuse for the present article.

A few days ago my attention was drawn to a report under the heading "*Prehistoric lake near Gulmarg: abundance of fossil plants*" recently published in the *Civil and Military Gazette* of Lahore.[1] Dr. R. R. Stewart of Rawalpindi, an American missionary and botanist, is reported to have expressed the view that there appears to have been "a lake some thousands of years ago at a height of 11,000 feet, just above Gulmarg".

This opinion is evidently based upon the fact, well known to Indian geologists, that lake deposits containing fossil remains, including modern species of aquatic plants and animals, occur on the slopes of the Pir Panjal Range, at altitudes where these species cannot exist to-day.

This brief article will attempt to explain to the general reader the significance of these high-level deposits, known to geologists as the Karewa Series. The Kashmiri name Karewa is applied to the more or less flat terraces or table-lands which cover a great part of the Valley, specially on the left bank of the Jhelum. In places these terraces are found sloping gradually up the mountains on either side of the valley; excellent examples are to be seen from the road between Srinagar and Gulmarg, on the two sides of the Ferozepur Nala, specially below Tangmarg. Recently they have even been traced up in a continuous series as far as the crest of the Pir Panjal Range, which bounds the Kashmir valley on the south-west.

For the information of those not familiar with Kashmir we may say that Gulmarg is a favourite summer resort at about 8,800 ft. altitude on the densely wooded NE slopes of the Pir Panjal Range. These slopes are thickly covered with the old moraines of glaciers which several times during the Pleistocene Ice Age, overran the greater part of Kashmir. Where the moraines are not covered with forest they form extensive undulating meadows, in the Kashmiri language called *marys*, as at Gulmarg, Khilanmarg, Sonemarg, etc. The Pir Panjal Range runs in a NW-SE direction, roughly parallel to the main Himalayan chain which lies east of it. The celebrated Vale of Kashmir, about 84 miles long and 25 miles in its broadest part, lies protected between these snowclad ranges, at a height of about 5,200 to 5,500 feet above sea-level. The river Jhelum issues from springs near the higher SE end of the valley and meanders peacefully through fertile plains to the NW end which is a few hundred feet lower. Here it escapes in rapids through a gorge near Baramula, only ten miles north of Gulmarg in a direct line. See map, Fig. 1.[2]

Ordinarily a casual newspaper report on a scientific matter does not deserve serious notice. But Dr. Stewart has been commissioned by an important scientific body—the Yale North India Expedition (popularly known here as the Karakoram Expedition)—to identify and describe the fossil plants from some of these lake deposits on the slopes of the Pir Panjal. And the conclusion he has arrived at directly conflicts with one of the main scientific results of the Expedition and, in fact, with long established geological evidence.[3]

The fossil-bearing sediments near Gulmarg, like many other deposits of clay, sand and

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* Except for the introductory reference to the press report, this article embodies the substance of an extension lecture delivered at the Punjab University, Lahore, on March 26, 1936.

[1] May 21, 1936, page 5.

[2] This map also illustrates another article in the present volume of *Current Science*, shortly to be published under the title. "*The Himalayan Uplift since the Advent of Man*".

[3] See *e.g.*, Wadia, *Geology of India*, 1926 (Macmillan), pp. 263–264, 383.