THE EOCENE BEDS OF THE KOHAT DISTRICT
by
Lt.Col.L.M.Davies, M.A., F.G.S.

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ATTACHED:
Text-figures 1-6.
Palaeontological Figures 1-53 (on two plates).
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Legend to Geological Map.

ACCOMPANYING:
Geological Map, coloured, of Eocene Beds, on Kohat district topographical sheets Nos.38/E/11,14 and 15, and 38/0/2,3,6,7,10,11,14 and 15.
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1. Location, Boundaries etc. of the District.

The Kohat district forms part of the North-West Frontier Province. It is bounded by the river Indus on the east, by part of the Peshawar district on the north-east, by the Tirah along most of its northern border, by the Puri country on the north-west, by Waziristan on the west, and by the Bunnu and Mianwali districts on the south-west and south-east respectively. Its shape is indicated by Text-figure 1, and its area is approximately 2,500 square miles.

2. Previous Geological Work on the District.

The geologist who did the most work on the Kohat district in the past as Mr.A.R. Wynne of the Geological Survey of India. He mainly dealt with the southern half of the district, and the results of his work on the same were published in two memoirs dated 1875 and 1880. Although stratigraphic terminology was less developed in his day than it is now, and the orthographical maps with which he was provided were much less accurate than those which are available to the modern geologist, Wynne's observations were so detailed and consistent, while dealing with this area, that the geology of the southern parts of the Kohat district can still be regarded as having been fairly well worked out. The regions covered by Wynne during these two surveys are indicated on Text-figure 1.

The northern parts of the Kohat district were also seen by Wynne, for he passed through them during the second Afghan war, but he had no time to examine them in detail. Much of what is now included in the northern half of the Kohat district was then still in tribal hands and could not be seen by him at all; and his movements were in any case restricted, by exigencies of time and transport, to the vicinity of the Khushalgarh-Thal road. Wynne's observations on this half of the district are recorded in a short paper dated 1879 (the martial spirit of the day appearing in his choice of a military term - which is incidentally misspelt - for the title of this paper). Although he succeeded in noting the general distributions of secondary and tertiary beds taken as wholes (no mean achievement under the circumstances) he was unable to map them exactly, and made no attempt to subdivide the scene into its component parts. Indeed, his unfamiliarity with the local sequence caused him to misinterpret the principal exposures which he saw,
Observations by later workers were very fragmentary, although Mr. C.L. Friesbach and Mr. (afterwards Sir Henry) Hayden, both of the Geol. Survey of India, published notes on the Samana range — which lies on the northern border of the Kohat district — in 1892 and 1893 respectively, after the military operations of 1891 and 1897 in that region. These notes did little, however, even to elucidate the geology of that range (which Wynne had been unable to approach); and although Dr. (now Sir Edwin) Pascoe of the Geol. Survey also published descriptions of the Eocene beds at Tarakhobi at the north-eastern end of the Kohat district, he said (p. 447) at the same time (1920) that little was known of the northern Kohat district west of the Indus. Hence Dr. G.B. Pilgrim of the Geol. Survey, when writing to me in the same year (1920) after hearing that I was to take over the command of a unit at Kohat, suggested that I should try to work out the geology of the northern parts of that district. The unit itself offered unique facilities for this, since it consisted of an artillery brigade with headquarters at Kohat and detachments in twelve other posts distributed over more than 400 miles of frontier, from Swat in the north to Baluchistan in the south. I therefore tried, while visiting outposts from 1920 to 1926, to compare the rocks found over this portion of north-west India, and in particular to work out the stratigraphic details of the less known parts of the Kohat district.

In doing this, I received much help from Dr. Pilgrim himself and from other Officers then on the Staff of the Geol. Survey of India, notably Drs. Coggin Brown and Cotter, and Messrs. Tipper and Wadia. I was consequently able to produce a number of papers describing the geology of Kohat itself, Bahadar Khel, Thal and the Samana range; the palaeontology of the same range being worked out in conjunction with British geologists after my return to England in 1926. I myself latterly concentrated on the study of the foraminifera, which I found to be the most important forms when dealing with the Kohat district, owing to the exceptionally fine development of fossiliferous Eocene beds in the same, while the local outcrops of older and younger beds are relatively unfossiliferous.

In my earlier papers I largely depended, for foraminiferal identifications, upon the opinions of the then official Palaeontologist in Calcutta; and I have since had to revise some of my conclusions after working out these forms myself, owing to the clarification in the meantime, through both Nuttall's work and my own, of Indian foraminiferal designations, which were a very unsatisfactory state until 1925. Nuttall's description of the upper Ranikot foraminifera of Sind was of great value to me in establishing the presence of Ranikot beds in the Kohat district; after which I further enlarged the list of systematically figured and described Ranikot forms to such an extent that, although only two foraminiferal species (both misidentified) had been regarded as characterising the Ranikot formation in 1925, the list of known Ranikot foraminifera is now as extensive as the corresponding lists of known Laki or Khirthar types. This has in turn facilitated the recognition of Ranikot beds by other workers — notably oil geologists — to have paid the most attention to Nuttall's and my palaeontological papers.

After proving the existence of Upper Ranikot beds at Thal (although it did previously been supposed that they did not extend north of Sind) I proved their extension over the whole of the Samana range. I also estab-
lished the existence of highly fossiliferous Lower Ranikot beds on that
range. These latter beds, which I termed the Ranig Shales, still consti-
tute the only really fossiliferous horizon known to exist in the Lower Ran-
kit. During recruiting work in the northern Punjab I also examined Pin-
fold's Chharat series, the stratigraphic position of which was uncertain
until I approximately determined it by comparing their foraminiferal con-
ents with those of the Eocene sequences in the Kohat district and Baluch-
istan.

Some years later, after retiring from the Army and graduating at Edin-
burgh University, I worked out Mr. Pinfold's foraminiferal collections from
the Punjab Salt Range, determining the exact stratigraphy of the Eocene
beds of that range, which had been completely misunderstood by previous
workers. I proved that the Eocene beds of the Salt Range belong to the
Ranikot and Laki stages (although the existence on it of Ranikot beds had
just been categorically denied by a senior Officer of the Geol. Survey),
and that Khirthar beds do not exist on it (although most of the beds had
been repeatedly referred to the Khirthar by another senior Officer of the
survey). I further showed that the Ranikot and Laki sequences on that
range can each be subdivided into three distinct zones; that the latest
Ranikot zone, named the Patala Shales by Pinfold and myself, is of later
age than any Ranikot zone yet found elsewhere; that the unconformity be-
tween the Ranikot and the Laki is less marked on the Salt Range than else-
where; and that the latest Salt Range zone, known as the Bhadrar
Shales, is older than the latest Laki zone of the Kohat district, which is
called the Shekhan Limestone from its development in the Shekhan nullah a
few miles east of Kohat.

This elucidation of Salt Range Eocene stratigraphy directly concerns
the Kohat district, since the western arm of the Salt Range forms the
south-eastern border of that district. It also (as explained later) helps to
date the first rising of the Salt Range axis; and so accounts for the
ferrostrated interlude of the Lower Chharat - in the Kohat district as well
as in the northern Punjab - and the shifting of deeper waters from the east
in the west in Khirthar times, which is testified by the Eocene stratigraphy
of the Kohat district.

After working out the Eocene succession on the Salt Range, I revisited
India in 1935-1936 in order to complete my survey of the northern parts of
the Kohat district, since most of the same had still never been visited or
depicted in detail by any geologist. I found on arrival that the Attock Oil
Company had advanced the mapping of the north-eastern corner of that dis-
trict from Tarkhobi to Gumbat, with some less accurate extensions further
east. This portion is indicated on Text-figure 1. I roughly checked this
survey, replacing what I regarded as inaccurate with my own version, and was
surveyed, by courtesy of the Attock Oil Company, to incorporate the parts of
their map with which I agreed with my map of the remainder of the northern
parts of the Kohat district, so as to form a complete supplement to Wynne's
maps of the southern parts of that district.

During my survey of the northern half of the Kohat district, I did a
considerable amount of work for the Attock Oil Company. This enabled me to visit
their principal sections in the Attock district, and to compare the sequences
with those of the Kohat district. I also received Mr. Pinfold's collections
from Waziristan, and paid a short visit to Waziristan myself. Al-
though, therefore, my survey of the Kohat district was single-handed, and I
solely responsible for all details shown on the map (excepting the por-
tion east of Gumbat), this later work to east and west of the Kohat district led to a clearer understanding of the relationships of the Kohat sequence to
sequences on either side of it. In all cases, the palaeontological findings
were my own, since I was officiating as advisor to the Attock Oil Company
while examining their field sections and collected material.

After completing my map, I proceeded to Calcutta. I there offered my
paper on the Boone beds of the Salt Range to the Geol. Survey of
India, and compared my collections from Kohat with their collections from
other parts of India. I also examined Sir Henry Haydon's Tibetan collec-
tions, since the exact age of some of the late Tibetan beds had been in
question for over thirty years. I found that some of these were packed with
typical Salt Range species, which I had just been describing in the Salt
Range paper; and I was able, in a few minutes, to identify so many Ranikot
species that the true age of some of the beds was fixed beyond dispute as
upper Ranikot, while others pertained to the Laki. I published this fact
as an Appendix to the Salt Range paper.

3. Topography.

The Kohat district is the most rugged portion of the North-West Frontier
Province. It is essentially mountainous, except to the south-east, where it
is penetrated by a tongue-like extension of the plains of the Punnum dis-
tect to the south. Its south-eastern border is nevertheless mountainous,
being formed by the crest of the Punjab Salt Range, which rises some 4,000
feet above the level of the adjoining plains, and swings to west and south
after crossing the Indus at Karabagh.

From Latambar and Kharak northwards, the Kohat district assumes a pro-
essively more mountainous aspect, the ridges becoming in general rather
higher and closer packed, while they run approximately east to-
until they reach the Waziristan border, where they swing southwards
like the Salt Range. The highest hills of all are found along the northern
border of the Kohat district, beyond which lies the still more mountainous
district of the Tirah. An extension of the Tirah ranges, passing eastwards to
east, intervenes between the Kohat district and the plains of the Feshawar
district to the north-east. Thus about half of the Kohat district (i.e. the
portion lying to north and west of a line drawn from Latambar to Gumbat)
constitutes a broad salient, surrounded on three sides by tribal territory
Waziristan on the south-west, Kuram on the north-west, and Tirah on the
north.

The town of Kohat, from which the district takes its name, is situated
at its northern border, where the most important and continuous of the
northern valleys, named the Miranzal, debouches to the east. Several other
valleys to east and west also debouch near Kohat, where a local patch of
at country, about 10 or 12 miles in diameter, varies the otherwise moun-
tainous topography of the region. Kohat is connected with the Punjab to the
east by some 40 miles of road and railway, across intervening ridges, to
Shabargarh on the Indus. To the west, both road and railway follow the
Miranzal valley, which skirts the Tirah border as far as Thal at the extreme
north-western limit of the district. Four frontiers meet at Thal, where
British territory forms a narrow triangular salient, with the Tirah to north-
east, Kurram to north-west, and Waziristan to south-west. The Miranzai valley is here joined by the Kurram valley, which passes north-west through the Turi country (the inhabitants of which, being Shiah Mahomedans, usually side with the British against the Sunni Mahomedans by whom they are surrounded) to the Peiwar Kotal pass into Afghanistan. Thus the Miranzai valley forms the lower arm of one of the two main approaches into India from Khaiber pass, which connects Kabut with Peshawar, some 40 miles to the north of Kohat.

It was via the Miranzai and Kurram valleys, and over the Peiwar Kotal pass, that Lord (then local Major-General) Roberts invaded Afghanistan in the winter of 1878-1879, while the main Afghan army was being engaged in the Khaiber pass; and it was at Thal, 40 years later, that General Dyer cut the Afghan chieftain Nadir Shah, who tried to invade India via the Miranzai valley during our domestic troubles in the Punjab.

Down the Kurram valley flows the Kurram river, passing through the point of the British salient at Thal, and then through the broader Waziristan salient to south of it, to enter British territory again near Bunnu, and finally to penetrate the Salt Range and join the Indus near Mianwali. Eastern tributaries of the lower portion of the Kurram river originate in the Kohat district, although most of the streams of the Kohat district flow in the opposite direction, to join the Indus above its junction with the Kurram. The watershed between streams flowing eastwards to the Indus, and westwards to the Kurram, may be represented by a line drawn from Kalabagh to Karbogha, and from Karbogha to Fort Lockhart. The upper portion of this line crosses the Miranzai valley near Kahe; and the level of the Miranzai valley rises steadily from Kohat (1,700 ft. above mean sea level) for about 40 miles to the (5,200 ft. above m.s.l.), and then gradually descends for about 20 miles to Thal (2,500 ft. above m.s.l.). The country round Kohat and Thal is generally bare of vegetation except in the vicinity of streams; but in the higher parts of the valley, for about a dozen miles on either side of Kahe, and for greater distances where the higher slopes are concerned, there is a considerable amount of vegetation, chiefly consisting of the dwarf palm (Mangra) scrub. The hillsides here being wooded, it is less easy to trace the geological sequence than it is to east and west, where the principal stratigraphic features can often be recognised from considerable distances.

4. Tectonics.

A marked line of discordance coincides with much of the northern border of the Kohat district, where a well-defined fault flanks the lower parts of the Miranzai valley and continues beyond that valley to the Indus. The beginnings of this fault, to the west, are hard to trace, but they probably were among a scattered collection of Mesozoic outcrops disposed round Thal, the upper part of the Miranzai valley. The fault becomes more distinct in the lower parts of the valley, but pursues an irregular course until it ache the vicinity of Kohat, where it straightens out and strikes in a ill defined and almost straight line to E.N.E. The amount of discordance connected with the fault also increases from west to east. Thus at Darsa, 52 miles west of Kohat, the fault is not visible as such, but valleys the north stand rather higher than the Miranzai valley, and the southern
limbs of intervening anticlines are inclined to dip more steeply than the northern limbs; at Hangu, 26 miles west of Kohat, the NW fault is clearly seen, although its course is irregular, and the greater steepness of the southern limbs of Tirah anticlines is most marked; opposite Kohat itself, here the course of the fault straightens out, the southern limb of the adjacent northern anticline becomes not only steep but reversed and over- thrust, Mesozoic rocks to the north overriding increasingly younger Tertiary ones to the south, as the fault is traced eastwards. At the same time, the Afridi salient to the north of Kohat here stands about 800 feet higher than the adjoining portion of the Kohat basin.

It seems clear that rocks to north of the Miranwali valley overrode rocks to the south, and that the displacement was most pronounced to the east, that the movement pivoted about Thal seems to be indicated by the grounding round Thal of Mesozoic outcrops, among which the successive folds of Tertiary rocks sometimes terminate to the west, and beyond which their continuations strike south-west and south through Waziristan and along the western order of the Punnu district. The southern strike of Tertiary ranges west of the Kohat and Punnu districts indicates that a thrust came from the west as well as from the north, and a southwards-striking fault in Waziristan estifies to the same fact; but the prevalent east-to-west strike of ranges within the Kohat district itself, and the very marked nature of the eastwards-striking fault along most of its northern border, etc., show that the thrust from the north was the one which principally affected its orogeny. The influence of both thrusts nevertheless traverses the whole district, and is well seen along its south-eastern border; for there the Salt Range, after crossing the Punjab from the east, swings round in a well-marked arch, strike southwards. Mesozoic and even Palaeozoic rocks outcrop in the Salt Range, the scarp faces of which - with associated fault at their base - on its southern and eastern flanks (speaking generally, and discounting regularities) with corresponding dip-slopes to north and west. Thus the angle formed by the Salt Range outcrop along the south-eastern border of the Kohat district reflects, and seems obviously related to, the angle formed by the outcrops running east and south from Thal at its north-western extremity; for Mesozoic rocks are common both in the Tirah to north of the Kohat district and in Waziristan to the west of it, although none (of any extent) appears within that district itself. One might roughly describe the Kohat rocks as forming part of a knee-bend of Tertiary and post-Tertiary sediments undered by Mesozoic outcrops.

LINING the Mesozoic rocks in all cases (Salt Range in the south-east, Afridi and Wazir mountains in the north and west respectively) appear Ranikot beds. As already stated, they were first shown to exist at Thal, on the Sonama, and afterwards on the Salt Range. I have since traced their outcrops along most of the northern border of the Kohat district into Waziristan, and also along the western borders of the Punnu district, beyond which a neglected outcrop which I long ago showed to exist in Zarind (29°55' 96") links them to the now classic Ranikot outcrops in Sind. When working through Carter's collections at the British Museum (Nat.Hist.) I also found Ranikot fossils on slide No.F.30214 from the Valley of Kalat (29°2':66'39") affords a further connecting link between the Ranikot beds of Kohat and those of Sind.

M.R. It is now obvious that Vredenburg's geological map of Baluchistan requires revision in the light of our greatly enhanced knowledge of Ranikot foraminifera. After probably referring too many beds to the
Ranikot in his earlier papers, Vredenburg reacted to excess in his later works and undoubtedly mapped a great deal as Laki which should have been shown as Ranikot. Unfortunately, nobody on the present Staff of the Geological Survey of India has sufficient knowledge of foraminifera to distinguish Eocene stages with certainty. Their inability to recognize the presence of Ranikot beds, even where the evidence is overwhelming, has been repeatedly shown by their attempts to deal with the Eocene formations of Waziristan, the Bunnu, Kohat, Peshawar and Attock districts, the Salt Range, and the Tibetan collections.

From the northern and western Mesozoic outcrops with their Ranikot fringes, to the south-eastern outcrops of the same kind, the entire central parts of the Kohat district are covered with later Eocene and post-Eocene beds. The numerous ridges which traverse this central region are mostly composed of outcrops either of anticlinal folds of hard Khirthar limestone, appearing between remnants of later beds, or of the separated limbs of such anticlines. Where the limbs are separated, there is often an alternation of anticlinal and synclinal valleys between successive ridges; these valleys being respectively occupied by Laki beds and post-Eocene ones. Nowhere that have seen do Mesozoic, or even Ranikot, beds appear in the central parts of the Kohat district.

It is noticeable, as also apparently bearing upon the fact that the principal thrust came from the north, that the foldings of these Tertiary rocks are more numerous and pronounced in the northern parts of the Kohat district than in its southern parts; to south of which, again, come the ranges which characterise most of the Bunnu and Mianwali districts. In the southern parts of the Kohat district, and more especially to the south-east, the synclinal valleys are broader than they are to the north and north-west; on the other hand, the outcropping anticlinal Khirthar ridges are generally narrower, and where their crests are excavated the resulting anticlinal valleys are narrower, and expose younger underlying rocks than are seen in the northern anticlinal valleys. Thus nothing definitely recognizable as older than the Lower Chharat is exposed in the southern parts of the district, although large exposures of Laki beds appear in the northern anticlinal valleys.

5. The Stratigraphic Succession.

Although such a well-marked change in the general orientation of hill ranges, from an eastwards to a southwards trend, takes place within this region, accompanied by faults showing corresponding thrusts from the north and west respectively, pivoting about Thal, it seems nevertheless clear that both to east and to south of Thal the orogenic features follow - and not cross - the general lines of deposition of late Mesozoic and early Eocene beds. Thus, to east of Thal, both lithological and faunistic species are relatively constant along the axes of orogenic features, whose strike is in that direction; while changes occur fairly rapidly in the opposite direction - from north to south. Similarly, to south-west and south of Thal, the nature of deposits is remarkably constant from north to south along the general strike of the hill ranges, while it alters rapidly from east to east across that strike.

Well marked, therefore, as the change in orientation of axes is, and
lear as the evidence seems to be of thrusting from two different directions at right angles to each other, it appears that these tectonic features sim-
ily follow, and accentuate, the pre-existing stratigraphic dispositions of these lesser ranges, between the Himalayas and the Hindu Kush, re-
te}ult from the efforts made by outlying parts of the major ranges to accomo-
revious marine sedimentation, which determined the lines of weakness along which subsequent strains produced their main effects. So whether we regard the hill ranges of the North-West Frontier Province as outlying portions of the Hindu Kush or of the Himalayas, their derivation, in course as in substance, seems mainly attributable to the disposition of later marine strata in that region.

Since the Kohat district lies in the pivotal area, covering most of the ee-bend where orientations change from an east-to-west strike to a north-
one, it might be expected to afford the best evidence for correlating the sandstone beds with southern ones; and this is in effect the case. Thus has not been easy, hitherto, to determine the relationships of the Giumal Sandstone and Chikkim beds of the Himalayan region to the Parh beds of the sandstones of Baluchistan; but I have found what I regard as transi-
ual links in the Kohat district. The Giumal Sandstone, capped by a fos-
iferous Gault horizon, seems to be a reduced equivalent of the "main sandstone series" of the Samana sequence, which is also capped by a fossili-
erous Gault horizon; while the abrupt transition in the east to the light-
doured Chikkim Limestone, which follows the Gault, is matched by the abrupt transition on the Samana to the "lithographic limestone" which succeeds the Gault in that section. Traced westwards from the Samana, however, these beds change in aspect, particularly near Thal, assuming facies much more like those of Baluchistan; for the "main sandstone series" gives place to sandstones, while the "lithographic limestone" locally exhibits collections of lemnites at its base, and develops - especially in its lower parts - a sequence much resembling the "Parh" beds of Baluchistan. Similarly the Hangu ndstone locally gives place, at Thal, to a great thickness (over 1,000 et) of sandstones which may well correspond with the "Fab" sandstones of the south.

It is noticeable that the greatest known developments of Lower Ranikot are found in the western parts of the Kohat district and in Sind, while in both these regions the Upper Ranikot terminates with the Khairabad Shales or its equivalents. Further to the east, in northern latitudes, the Lower Ranikot tends to disappear, but very late Ranikot elements (the Thal Shales) succeed the Khairabad Limestone.

With the advent of the Laki, however, the northern deposits adopted facies of their own, even in their western parts, which are worth noting. The Laki, which is well developed both in Sind and Baluchistan, is very orly developed indeed in the western parts of the Kohat district, although more developed to the east. Thus very early Laki deposits are found on the Salt Range (and therefore on the south-eastern border of the Kohat district) which are probably earlier than anything hitherto found in Sind or Baluchistan, and would seem to represent some of the elements whose absence is indicated by the "Lower Laki Laterite" of Nuttall's southern sequence. The Sakesar Limestone of the Salt Range may be equivalent to the Dunghan mestone of Baluchistan, and the Bhadrar beds of the Salt Range to the Met-
Shales of Sind; but the facies are rather different. These beds are al-
This progressive reduction and early disappearance of Laki beds to the west is a remarkable fact, whose significance should not be overlooked. I found no beds of Laki age in northern Waziristan, although both Ranikot and Khirthar beds are present there. Nor do any Laki fossils appear in Mr. Pinch's collections from southern Waziristan, although Ranikot and Khirthar fossils abound in them. Statements by Dr. A.M. Heron, the present Director of the Geological Survey of India, to the effect that Dr. Coulson found Laki beds in Waziristan, are totally unsupported by fossil evidence - as he admitted when I asked for such evidence. Indeed, he made it clear that Dr. Coulson depended solely upon the lithological resemblance of certain Waziristan beds to ones in the Sherani country which Vredenburg had tentatively ascribed to the Laki. But even the latter were unfossiliferous; and Vredenburg had correlated them on lithological grounds with ones still further south, in Baluchistan, which he had referred to the Laki, but which I have once shown to include Ranikot beds.

The fact is that (as Vredenburg himself pointed out) lithologically similar beds occur at many levels on the north-west frontier of India, from upper Cretaceous to later Tertiary times. So the case, as known at present, is that Laki beds are best developed in the eastern parts of the Kohat district, and on the Potwar plateau to the east of it, and progressively diminish to the west; the last remnants of the latest Laki beds being found a few miles east of Thal. Laki beds do not exist in northern Waziristan; and they have not yet been shown to exist either in southern Waziristan or in the Sherani country still further south, although they undoubtedly exist in Pakistan. There is every reason for concluding, on the present state of the evidence, that the Afghan coast approached India at the close of the Ranikot, probably owing to the emergence of northern Afghanistan, with relation to India, at that time. This would have continued the previous emergence, in the Cretaceous times, which freed northern Afghanistan to a large extent from the waters of the great Cenomanian transgression which had temporarily covered the whole of it.

In order to appreciate the effects of this further (latest Ranikot or Laki) emergence of northern Afghanistan upon sedimentation in the Kohat district, it is necessary to recall the general distribution of the Ranikot sea.

The Indian sea of Palaeocene times had apparently become segregated from European waters, owing to the breaking up of Tethys at the close of the Mesocene. I infer this segregation from the marked distinction of Indian Ranikot foraminifera from the contemporary foraminifera of Europe. The Indian species which Vredenburg and Nuttall identified with *N. planulatus* is really distinct from the latter, and I redescribed it as *N. nuttalli*. It is a central member of a remarkable group of forms which has no parallel in European deposits, and includes the singular genus *Miscellanea*; and it is accompanied by other well-marked species and even genera which have also not been found in Europe (e.g. *Lockhartia haimi, Sakesaria cotteri, Dictyocoides flemingi, Polylepidina punjabensis* etc.).
Segregation alone seems able to account for this marked distinction of Ranikot forms from European ones; for there is no great difference in longitude between some Upper Ranikot deposits and those of Europe, and the distinction between Indian and European faunas becomes rapidly less after the Ranikot.

At the same time, it is clear that segregation could not have commenced before the Danian; for Vredenburg found the characteristic Upper Maastrichtian species Omphalocyclus macropora in many parts of Baluchistan from Las ela in the south to the Mari hills in the north, I myself recently found it in Kohat deposits, and both Vredenburg and Douville recorded its appearance in collections from Tibet. It is therefore clear that direct communication between western Europe, India and Tibet must have continued until late Maastrichtian times.

Segregation nevertheless existed at the commencement of the Tertiary. The extent of the Lower Ranikot sea is not known yet, owing to the generally unfossiliferous nature of Lower Ranikot beds, and their often obviously fluviatile character; but the presence of Ostrea and Cardita, and marine beddings in certain basai Tertiary beds of southern Afghanistan and Sind indicate marine conditions there, and the discovery of richly fossiliferous Lower Ranikot beds (the Hangu Shales) in the Kohat district indicates that marine estuary must have penetrated as far as the Samana range and there turned eastwards for at least 40 to 50 miles.

The course of the Upper Ranikot sea is much more easy to trace, owing to the highly fossiliferous nature of most of its sediments. The Ranikot sea attained its maximum distribution in early Upper Ranikot times. I have seen elsewhere that its deposits extend from Shamshir-i-Guli (33°50' 47°10') in western Persia to Kampa Dzong (28°21' 88°30') in Tibet. It apparently covered a great area that is now land in southern Persia, southern Afghanistan, western Baluchistan, and Sind, while a singularly long and relatively estuarine passed eastwards across northern Baluchistan, turned northwards along the line of what are now Waziristan and the North-West Frontier Province to about 50 miles south of Kabul, where it again turned east, passing over the Kohat district, much of the Tirah, and much of the Peshawar, Attock, Rawalpindi and Jhelum districts, towards the present north-west Himalayas which apparently crossed in the vicinity of Singhia La in Zanskar. It then passed south-east and east, skirted the southern borders of the Naran-Marwar Lakes, and reached as far (at least) as Kampa Dzong south of the Shapmaputra. Text-figure 2 indicates the Indian portion of the Upper Ranikot sea, as reconstructed by myself from the present state of the evidence as to the distributions of Upper Ranikot outcrops.

It will be seen that the Kohat district covers most of the western half of a sector of the Upper Ranikot sea which extended from Waziristan in the west to what is now the Pir Panjal range in the east. Since the Potwar plateau covers most of the eastern half of this sector, I propose to term the whole sector the "Kohat-Potwar basin." The western end of the basin is connected via Waziristan and the Sherani country etc. with the open sea on the south, while an extension from its eastern end crossed the present Malayan axis and continued to Tibet.

It will therefore be realised that the further emergence of Afghanistan at the commencement of Laki times, which has already been mentioned, both displaced and narrowed the communications of the Kohat-Potwar basin with the open sea; an important fact when studying the geological history of
his area. This emergence may well have been correlated with other earth
movements leading to the destruction of the barrier between Indian and Euro-
pean waters, for the fauna of the Laki witnesses to an increasing infusion
of European species of foraminifera, in the Kohat district as elsewhere.

Other marked developments during the Laki are evidenced to the east of
the Kohat district rather than within it; for it is clear, from the disturb-
ance shown by Laki sediments along the flank of the Pir Panjal range, and
from the displacements northwards and outwards of Laki sediments in Kashmir,
as and Ladak, that the north-west Himalayan axis began to rise in Laki
times. That it finally severed connections between the Kohat-Potwar basin
and its trans-Himalayan extension by the end of Laki times, is indicated by
the absence of any known deposits of later age in the trans-Himalayan region.
reconstruction of Indian marine geography in early Laki times is shown by
ext-figure 3. It will be noted that the main evidences of disturbance oc-
cur at the two ends of the Kohat-Potwar basin, which is shortened and broad-
ed as a consequence. The trans-Himalayan extension of the earlier sea is
placed only at its junction with that basin; the Kampa Dzong Laki beds,
the upper end of that extension, succeed the Ranikut without such dis-
placement.

Soon after the Himalayan axis began to emerge, the Salt Range axis seems
to have commenced rising. This event, although less interesting than
the initial rise of the Himalayan system, had a more direct effect upon
stratigraphy within the Kohat district itself, and is also partially wit-
essed within the district since it contains the western limb of the Salt
range. Thus although the Eocene sea (which shallowed after Koharabad Lime-
stone times, and remained shallow during the succeeding uppermost Ranikut
Shale, and lowest Laki Narmal Shale, periods) deepened over the Salt
range area during the Sakesar Limestone phase, it shallowed again - and
finally - while the Khadrar beds of Upper Laki age were being deposited,
the later beds of a marine nature are found on the Salt Range, nor do any
Khirhar marine beds appear even in its vicinity. On the contrary, later
marine beds are progressively removed from its vicinity; Khirhar ones being
found further from it than latest Laki ones, and the later Khirhar further
than the earlier. This seems to indicate that the Salt Range axis also rose
at some extent during later Laki times.

As might be expected from such an event, after the displacement and nar-
welling of communications with the southern sea, desiccation ensued of the
remaining marine contents of the Kohat-Potwar basin. It is probable that a
continuation of the western end of the young Salt Range axis formed a bar or
local across what remained of communications with the south, while the wat-
ters of the basin retreated northwards and north-westwards from the Salt Range
region. It is there - i.e. to north-west of the Salt Range - that the main
issum and Salt deposits of unmistakable Tertiary age are found; and it was
probably there, opposite what remained of communications with the south,
that periodic fresh incursions of marine waters entered the Kohat-Potwar
basin, to add their salt contents to what had already been concentrated out,
such as the Karobghaz Gulf of the Caspian Sea is becoming increasingly more
line at the present day.

Following upon the latest Laki phase of this region came the lacustrine
fluviatile Lower Chharat phase, the circumstances leading to which I be-
lieve are here explained for the first time. Since no other geologist has
concentrated as I have on the study of the Eocene foraminifera of this re-
on, no other has been able to distinguish both the stages and the zones
of the Eocene represented by the various nummulitic deposits of these parts, once other geologists have not been able to distinguish confidently between remnants of different Eocene phases, they have generally supposed that because Eocene beds appear both on the Himalayas and on the Salt Range, both Himalayas and Salt Range rose after the Eocene; whereas I hold that they rise during the Eocene, and within the same stage of the Eocene, although one movement began earlier in that stage than the other.

It now seems for the first time possible, as a result of my work on the deposits of the Kohat-Potwar basin, to understand why desiccation followed the Laki in that region, and why a fluvial interlude succeeded the desiccation. All the evidence seems to be consistent. The distribution of the Eocene sea at the close of Laki times is indicated by Text-figure 4.

The Kohat-Potwar basin seems to have remained much the same, as to general shape, during Lower Chharat (Lower Khirthar) times as it had been during the Shekhan Limestone period (the latest Laki phase). This is well seen in the Kohat district, where Lower Chharat beds become progressively thinner and coarser in type towards the west, just as the underlying Shekhan Limestone ones become thinner and shallower in nature towards the west. Indeed, both sets of beds finally terminate along much the same line, for the last segments of Lower Chharat conglomerates were seen by me at Thal, only a few miles beyond the last traces of Shekhan Limestone deposits; and the Lower Chharat, like the Laki, was not found by me in northern Waziristan, where Upper Chharat (Middle Khirthar) marine beds overlap directly onto the Ranikot. This must indicate the shape of the basin itself, and cannot be due to subsequent denudation. The parallel changes in type towards the west of two successive formations, and their similar ding at about the same meridian, give what I regard as unequivocal evidence of the shallowing of the basin with the west.

I also found that the Eocene succession west of Saidgi, on the Waziri border W.S.W. of Bunnu, shows Middle Khirthar beds immediately overlapping onto Upper Ranikot ones, the Lower Chcharat being absent as well as the Laki, just as both are absent opposite Thal over 30 miles to the north. We thus good reason for concluding that the Kohat-Potwar basin had greatly reduced connections with the south during Laki times.

That some such connection did survive, however, even to the end of Laki times, is indicated by the presence (long ago noted by Wynne, and recently confirmed by Pinfold and myself) of small marine molluscs in the lowest levels of the Lower Chharat beds about 2 miles W.S.W. of Barbara Banda village (31°15'44"N, 71°16'41"E). I found that the Nummulites, which are also mentioned by me, are not in situ. They are typical Upper Chharat forms, and occur in limestone masses which have obviously slipped down from the overlying Upper Chharat beds. But the molluscs have every appearance of being in situ, being them exists at any higher level; and their matrix is of Lower Chharat type, in perfect keeping with the unfossiliferous Lower Chharat layers among which they are found. Dr. L. R. Cox of the British Museum (Nat. Hist.) since described these molluscs, so far as their state of preservation permitted. Mr. E. R. Gee of the Geol. Survey of India has reported finding marine molluscs at a similar level near Bahadur Khel (33°11'56"N, 70°57'11"E) and Jatta (30°20'47"N, 71°15'27"E), but his forms have not yet been figured or described. It is worth noting that these latter exposures are slightly to south-west and north-east respectively of Barbara Banda, and may indicate the line of a residual marine connection.

Although the shape of the Kohat-Potwar basin does not seem to have alt-
red between latest Laki times and Lower Chharat ones, there is good evidence that it changed to some extent with the advent of the Upper Chharat marine phase. For it seems certain, not only that the land sank at the close of Lower Chharat times, but that the basin itself acquired a degree of tilt to the west when it did so. Thus the immediately succeeding Kohat Shales are most calcareous in type and most fossiliferous towards the west, and least so towards the east; the Nummulite Shale, which follows the Kohat Shale, is not really a shale but a limestone to the west of Kohat, and is most truly a shale to the east of the Indus. The succeeding massive formations, which I propose to call the Kohat Limestones, are not found at all to the east, but only appear in the Kohat district.

These facts, together with the fact that the Upper Chharat and succeeding beds transgress far over Waziristan to the west, clearly indicate, in my opinion, that the shape of the basin of deposition changed at the close of Lower Chharat times. Not only must the land have sunk as a whole (as the reappearance of marine beds testifies) but the basin must have acquired tilt to the west, making its eastern portion the shallower part instead of remaining the deeper as it had been during the Laki and Lower Chharat. do not agree that a large amount of later Eocene beds has been removed from the eastern parts of the basin, by denudation prior to the deposition of Murree beds there (as some have suggested); because the peculiarly shaly character of the Nummulite Shale (which derives its designation from its eastern aspect) in the Chharat region, indicates that the sea was actually shallower there than it was to the west. The significance of the increasingly calcareous nature of the same bed, as traced to the west, is no more to be mistaken than the significance of evidence of an opposite kind in regard to the underlying Lower Chharat and Laki beds. The basin had acquired a tilt in the opposite direction; and the fact that no fragments of later beds arrive to the east, even in faulted regions, although they are so well developed to the west, suggests that the tilting was progressive, and continues during the later phases of the Khirthar.

If we look further to the east, beyond the Chharat region, we find that the Nummulite Shale itself is either missing or else represented only by ambiguous fragments (Wadia's "Jokan" beds) whose very nature indicates further modification in the nature of sedimentation.

This tilting of the basin need not indicate a tilting of the land as a whole. I suspect that it was due to further emergence of the Himalayan and Salt Range axes, which would lead to the relative shallowing of the eastern mid-southeastern parts of the basin, even though the land in general sank in epeirogenic fashion. In other words, although Afghanistan sank to some extent under the sea, it is not necessary to suppose that it sank so differentially, in regard to north-west India, its relations to which I think probably remained unchanged.

The Kohat Limestones (as I propose to call them) are of post-Chharat age, but conformably succeed the Nummulite Shale (the latest Chharat member); the transition being well seen in the Shekhan nullah section near Kohat, where the Nummulite Shale is still rather imperfectly indurated and lithologically distinct from its successors. Further to the west, the representatives of the Nummulite Shale are really limestones, and only distinguishable from their successors by their rather more flaggy nature.

The Kohat Limestones are less fossiliferous in general (except to-
wards the top) than the Nummulite Shale; but they apparently belong to the same zone as the latter and the Kohat Shale, namely, the Middle Khirthar.

Succeeding the Eocene marine beds, from Chharat in the east to Waziristan in the west, derived fossils from those beds often appear in the lower levels of the superimposed later Tertiary fluviatile sediments (which are Murree type round Kohat and to east of Kohat, but give place to Kamlials and other meridians of Bahadur Khel, and are of Chinji age near Thal and Ari age in northern Waziristan). The layers with derived fossils constitute Pinfold's "Fateh Jang" zone to the east; but it is simply a contact zone never found, being dated according to the matrix locally containing the fossils.

Between Hangu and Sarozai, however, I found fragments of true marine shales succeeding the Kohat Limestones, and intervening between them and the fluviatile beds. The matrix of these shales was distinct from that of the later Tertiary sediments; and the fauna of the shales was also obviously derived from any lower beds, since it was distinct in type and indicated a later horizon. I found that it corresponded with the fauna which I collected from the uppermost levels of the Khirthar section at Spintangi, in northern Baluchistan, which is the type area for the Spintangi, or Upper Khirthar, beds which Vredenburg cited as being well represented in Baluchistan and Sind.

These shales, which are the latest Eocene beds found by me in the Kohat district, are the only representatives of the Upper Khirthar that have been discovered so far north. It is worth noting that they appear in what had probably been the deepest parts of the Kohat-Potwar basin in later Khirthar strata. It seems significant that I found an Ostracod of the genus Cytharae them, indicating a last return to estuarine conditions before the sea finally abandoned this region.

I now propose to describe in detail the succession of beds which has been outlined above in more general fashion. I will commence with the later Mesozoic formations, as introducing the Eocene ones.

**The Upper Jurassic (= later Kioto) Limestone.**

The lowest Mesozoic formation which I have continuously traced in the Hazara district is the one which I called the Samana Suk Limestone, in my description of the Samana sequence. It is the most constant of all local formations, about 500 feet thick on the Samana itself, and consists of a dark grey crystalline limestone, generally unfossiliferous, but locally showing traces of Cephalopods, Brachiopods and Crinoids. Its uppermost layers sometimes assume a brecciated aspect (very like that of the Hangu Breccia) and in other places are distinctly dolitic. It corresponds, both in time and in stratigraphic position, with a massive limestone, with a massive limestone, 500 to 1600 feet thick in the Attack and Hazara districts, which Cotter identified with Hayden's Kioto Limestone of Spiti and Kashmir, which is sometimes over 2,000 feet thick. At the same time, since Cotter states that the Kioto Limestone ranges from the Noric to the Callovian, it still seem that the Samana Suk Limestone of Kohat can only correspond with its uppermost levels; for I found a Brachiopod which Miss H.Muir Wood regards as a Callovian - possibly Bathonian - type in shales immediately underlying it near the Samana Suk. The base of this limestone is not seen in more eastern exposures; but its thickness cannot be less than 700 to 800 feet at
The Neocomian Belemnite Bed (= Spiti Shales).

Following the above-mentioned limestone on the Samana Range come about to 50 feet of glauconitic sandstone, packed with Belemnites. Since an monite which I found at this level near Thal was regarded by Dr. L. F. Spath indicating a lowest Hauterivian age, this bed was treated in my Samana per as being a Neocomian formation. It may thus be correlated with the Spiti Shales, which range from the Argovian to the Valanginian according to tetter, and succeed the Kioto Limestone in Spiti, Hazara etc.

This bed varies a good deal in nature when traced to the west, but always seems to contain an abundance of Belemnites. At Darsamand it consists from 20 to 30 feet of olive and red shales, full of Belemnites. On the uth-western slopes of Kadimak mountain, near Thal, it is no longer distinguishable as a separate lithological unit, but is represented by numer-
s Belemnites near the base of a great thickness of otherwise unfossilifer-
s; olive shales which succeed the Samana Suk (upper Kioto) Limestone.

The Lower Cretaceous Sandstones (= Giumal Sandstone).

These are represented, in the Samana section, by about 700 feet of artizitix sandstones, with shale partings, which I called the Main Sand-
one Series in my description of that section. I showed that, being capped a Gault horizon, this formation probably corresponds with the Giumal
stone of Spiti and Hazara, the Giumals of Hazara being similarly capped a Gault horizon. Dr. Cotter, who went more fully into the matter soon afterwards, came to the same conclusion. It is clear, however, that the sandstone is much more largely developed on the Samana than to the east.

To the west of the Samana, this bed also changes its character. At Dar-
amand, the formation is still a quartzitic sandstone, up to 500 feet in thickness; but in the section on the south-western flank of Kadimak mountain Thal it is seen to consist of some 550 feet of shales only, of which the wer 450 feet are olive shales (full of Belemnites at their base), and the per 100 feet are pinkish to purplish shales and light-coloured bands with ant remains.

The Gault Band.

This is a highly fossiliferous, calcareous and phosphatic grit, only hut 5 or 6 feet in thickness, which caps the Main Sandstone Series on the Samana. According to Dr. Spath, its fauna (which includes many specimens of Villeliceras mamillatum Schlotheim) indicates a Middle to Upper Albian age. A very similar assemblage (also including Douvilleiceras mamillatum) appears in the Gault of Hazara, immediately above the Giumal Sandstone.

During my recent visit to the Kohat district I noted the presence of Belemnites in some exposures of this bed, and found that the bed itself does continue much to the west of the Samana. Thus I could not find it in
The Darsamand section, its place being taken by a rather coarse conglomerate, 2 to 3 feet thick, containing large limestone pebbles and occasional Belemnites. This conglomerate continues to the western limits of the Kohat district, being well represented at the corresponding level in the southwestern Kadimak section, where it is even coarser, some boulders in it assuring 2 feet in diameter. It is there from 3 to 8 feet thick, and still contains occasional Belemnites.

**The Upper Cretaceous Limestones (= Chikkim Limestone = ? Parh Beds).**

On the Samana, as to the east, there is an abrupt transition from Gium-Sandstones and Gault to succeeding fine-grained limestones. I called the latter Lithographic Limestones, in the Samana paper, and remarked on the unconformity between them and the underlying Gault grits, pointing out the unconformity was emphasised by the presence of derived Gault fossils in the lower levels of the limestones. Probably the coarse conglomerate which replaces the Gault to the west gives further evidence of this unconformity.

I think that these limestones can - as already suggested in the Samana paper - be correlated with the Chikkim Limestone of the Himalayan region, which similarly succeeds the Giumai Sandstone. The formation is doubtless Upper Cretaceous age, since it is both pre-Ranikot and post-Albian. Parts of these limestones show no traces of fossils on sectioning; others are full of minute foraminifera, and resemble the Chalk of western Europe.

These limestones, locally divided into two masses separated by sandstones and shales in the western parts of the Samana range, are still recognisable where they consist of some 200 to 300 feet of limestones, which develop a pink and white cherty facies recalling the Parh beds of Baluchistan.

In the southwestern Kadimak section the change becomes very marked, and is difficult to know where to draw the line between this formation and the next one. I provisionally allot the following beds of that section to this group, taking them in ascending order:

(a) Purple and green shales, with white calcareous bands, often assuming resemblance to Parh beds, and locally containing many Belemnites near their base ........ 320 ft.

(b) Massive light-coloured sandstone, with spongy grit on top (dun-coloured in other sections, and sometimes locally replaced by a conglomerate) ............... 100 ft.

(c) Purple and green shales (locally containing some oolitic and other limestone bands or lenticles) ........ 100 ft.

These three sections may correspond, respectively, with beds 5, 6 and 7 of the Samana sequence.

Although these beds seem to be continuous with the Lithographic Limestones of the Samana section, and so may be correlated through them with...
The Chikkim Limestone of the Himalayas, their facies, especially in their lower portions, resembles that of the Parh beds of Baluchistan, which incidentally show a similar abundance of Belemnites at or near their base. Thus the Kohat district deposits help to correlate the Himalayan Cretaceous sequence with that of Baluchistan.

It should be noted, however, that the above-described Mesozoic sequence in the northern and north-western parts of the Kohat district is fuller than the Mesozoic sequence on the Salt Range, the western limb of which forms the south-eastern border of the Kohat district. Only the lower parts of the Lower Cretaceous beds, with the Belemnite bed and the underlying Jurassic (Kitoi) limestone, are found on the western end of that range. The last of the Cretaceous beds seems to disappear in the Chhidru area, and the last of the Jurassic beds disappear near the Nilawan gorge. Thus the succeeding Eocene beds of the Salt Range area overlap onto an increasingly older Mesozoic and Palaeozoic surface when traced to the east.

**The Hangu Sandstone.**

This is the lowest formation which I referred to the Eocene in my description of the Samana sequence; and if rightly so referred, it is the best known Eocene formation in the Kohat district. It consists, on the summit, of about 140 feet of white quartzitic sandstones, variously banded mottled by iron oxides, and is indistinguishable in appearance from underlying Cretaceous sandstones of the same section. My only reason for assigning it to the Lower Ranikot is that its upper levels (which locally contain many small angular blocks of limestone) become very calcareous, and less with apparent conformity into the highly fossiliferous Hangu Shales ofoubted early Ranikot age. There is thus no reason for postulating an unconformity between the Hangu Shales and this bed, while fairly good reason exists for suspecting an unconformity between this bed and the underlying Lithographic Limestones.

My recent more general survey of the Kohat district produced no evidence conflicting with this opinion; although it showed that this bed, like its predecessors, changes greatly in the vicinity of Thal. It does not, however, change in the same gradual way as its undoubted Mesozoic predecessors. The Darsamand section it is practically unaltered, true to type in every respect, and about 100 feet thick. Even on the eastern and south-eastern slopes of Kadimak mountain it is still perfectly recognisable, and from 100 to 150 feet in thickness. It still contains - there, as at Darsamand and the Samana - local accumulations of small limestone blocks embedded in a upper surface, which is calcareous and succeeded by a small quantity of fossiliferous Hangu Shales.

On the southern and south-western slopes of Kadimak mountain, however, the succession changes with astonishing rapidity. The formation is first, in an incomplete section, to be represented by a considerable thickness of dun-coloured sandstones and grits with olive shale partings, which are succeeded by 400 feet of what are probably olive shales but are mostly veiled by detritus, the whole being capped by 55 to 60 feet of Lockhart limestone. These sandstones and grits contain small foraminifera of Ranikot types.

On the south-western slopes of the mountain the change is even more marked. I have already referred beds (a) to (c) of that section to the
upper Cretaceous, and correlated them with the lithographic Limestones of the Samana sequence; the following immediately succeeding beds would in that case represent the continuation of the Hangu Sandstone:

(d) Brown, black-weathering sandstone ............... 30 ft.
(e) Coarse conglomerate, with very ferruginous matrix (some of the pebbles in it contain Omphalocyclus macropora Lamarck) ............... 30 ft.
(f) Brown, black-weathering sandstones, with subordinate green shales ..................... 1,000 ft.
(g) Olive shales, with one or two subordinate bands of black-weathering sandstones .......... 230 ft.
(h) Fine conglomerate, with Orbitolina and fragments of Belemnites, Corals, Crinoids, Echinoids, pebbles of oolitic and other limestones and of black-weathering rocks etc. ........ 2 ft.

After this come shales etc. with Upper Ranikot fossils. The sequence so unfamiliar in type that it suggests faulting; but the presence of Omphalocyclus macropora in pebbles of bed (e) indicates that that bed must of post-Maastrichtian age and is probably Tertiary. The enormous thickness of sandstones in bed (f) has no place in the local lower sequence; and en the Orbitolina in bed (h) seem foreign to the local sequence (like any of its other contents) and were probably derived from beds to north or north-west of Thal. The same applies to the Omphalocyclus, which I have yet seen in any sections of local rocks found in situ.

Although, therefore, the area is rather a faulted one, I cannot regard the beds of the south-western Kadimak section as belonging to a lower portion of the local sequence. It seems necessary to accept the fact that the region was one of abnormal deposition. Three miles south of Kadimak, Kurram Picquet hill just south of Thal Fort, there are over 700 feet of black-weathering sandstones and green to brown shales, largely fossiliferous and of Ranikot age, underlying more than 600 feet of shales capped by typical Upper Ranikot beds. These sandstones I long ago referred to the lower Ranikot. It seems to me that the successive conglomerates in the region, and the great accumulation of sandstones - possibly contemporary with the Pab sandstones of Baluchistan - probably indicate that a north-eastern river discharged its contents in this region. A noticeable feature of the Kadimak sandstones is that they contain a considerable number of well-rounded quartz grains. These probably came from northern Afghanistan, which have had little vegetation and developed desert conditions after emerging from the Upper Cretaceous sea.

I therefore provisionally regard the great thickness of unfossiliferous sandstones of the south-western Kadimak section as representing a delta, of which the more fossiliferous sandstones exposed at Kurram Picquet etc. represent the seaward aspect. Since this river probably followed a course far removed from that of the present Kurram river, I propose to refer it as the (still rather hypothetical) proto-Kurram river (see Text-figure 2).

A southern (equally hypothetical) river which I postulate on grounds
which cannot be detailed here, I will refer to as the proto-Sarasvati river, both rivers, if they existed as I suspect, came into prominence in Lower Ranikot times, although both began to take form in the Cretaceous.

The Hangu Shale.

I recently traced this bed from Bar Jangal village, a little north-east of the Samana, to the south-eastern slopes of Kadimak mountain at Thal. It is never more than a few feet in thickness (2 to 20 feet on the Samana); but it seldom fails to appear, with some of its characteristic fossils, between the Hangu Sandstone and the Lockhart Limestone where every the junction of those two formations is seen. The fauna of this bed mainly consists of illuscos, which have been described by Dr. L. R. Cox; while its corals were allied with by the late Prof. J. W. Gregory. It contains few foraminifera; but found at least one foraminiferal species of stratigraphic value in it, namely Lockhartia haimei, a typical Ranikot form which has never yet been seen in any but Ranikot sediments.

As might be expected, this very narrow bed disappears as soon as the nature of the local sequence changes; it has only, so far, been found in the Ranazai valley. On the other hand, its persistence along nearly 40 miles of the northern border of that valley indicates that the valley itself must approximately coincide with the shore-line of the estuary in which these sedges were deposited. I therefore conclude that the early Ranikot sea, a narrow tongue of which may or less intermittently have reached as far north as Thal, probably managed, when the land began to sink later in Lower Ranikot times, to cross the mouth of the proto-Kurram river and extend eastwards towards Kohat along the bed of the preceding Cretaceous sea, whose rise in that direction is indicated by the continuity in it of preceding low-water formations (such as the Belemnite bed, the Gault band, and Hangu Sandstone itself).

The Lockhart Limestone.

This limestone is the most massive one pertaining to the Ranikot in the Kot district. Where seen in its entirety, as below Fort Lockhart on the Samana range, it is 200 feet thick. Portions of it (base not seen) outcrop erratically along the fault line in the lower parts of the Miranazai valley east of the Samana, to about the meridian of Kohat itself; after which increasing degree of overthrust conceals it from view in the north. At Shobi, however, more than a hundred feet of it are exposed; and its continuation beyond the Indus seems to be represented by 80 feet of Ranikot limestone near the base of the Ranikot sequence on the Kalachitta range, 11 miles north of Domel.

To west of the Samana range, this limestone can be continuously traced as Kadimak mountain, where it last appears as a mass 55 feet thick, dipping 60° to the south, on the southern flank of that mountain. There, as at Lockhart, its uppermost layers are cherty and full of foraminifera.

The upper portions of this limestone are certainly of Upper Ranikot age; I think the greater part of it probably corresponds with the Dhak Pass and succeeding Khairabad Limestone of the Salt Range sequence, both of which I would refer to the Upper Ranikot. I think, however, that the Hangu
ale fauna indicates an older horizon than that of the Dhak Pass beds; and regard the lower parts of the Lockhart Limestone, where found in immediate sequence to the Rangu Shale, as being probably of Lower Ranikot age.

At Thal, the Lockhart Limestone terminates rather abruptly. Although its actual end is hidden under later beds, it is still at least 55 feet thick when last seen, and yet makes no reappearance a few miles west and north where later Mesozoic and early Eocene rocks again outcrop. This may be due to the disturbing influence of the proto-Kurram river. Upper Ranikot beds to west are predominantly shaley and unfossiliferous; although some fossiliferous layers, and certain more sandy ones, are highly fossiliferous. The presence of numerous corals in some of these layers indicates clear water. I suspect that rainfall was small, and that occasional long periods of drought tended to clear the waters and allow of temporary invasions by rich marine faunas. The Upper Ranikot beds of Waziristan, so far as these are marked, no traces of Eocene beds are associated with the outcrops of older beds which occur only 25 miles south of the Salt Range. Conditions here indicate shallower water than on the Samana; but there is not the same evidence of the presence of a river that one finds in the Thal region.

The Khairabad Limestone.

The Khairabad Limestone of the Salt Range - which I correlate with the upper portions of the Lockhart Limestone - is a nodular formation and much more massive than the Lockhart Limestone. Its overlap onto a progressively finer surface indicates that the border of the Ranikot sea cannot have passed much beyond the limits of the present Salt Range; and as Sir E. Pascoe has marked, no traces of Eocene beds are associated with the outcrops of older beds which occur only 25 miles south of the Salt Range. Conditions here indicate much more similar facies to that of the Khairabad Limestone, less fossiliferous shales, with occasional highly fossiliferous layers in them. The sea was apparently less deep in Waziristan than in the Kohat basin, and fluviatile influences were more marked.

As already remarked, the Ranikot sea seems to have reached its maximum development in Khairabad Limestone times. The collections from Shamshir-i-n in western Persia, and from Kampa Dzong in Tibet, alike show a remarkable similarity in foraminiferal facies to that of the Khairabad Limestone. Conditions must have been very equable over great distances to have produced this similarity; and its extent - over more than forty degrees of longitude - indicates that segregation must be invoked, rather than distance, to account for the distinction of Indian Paleocene forms from European ones.

A noticeable feature of the Ranikot deposits in the Kohat-Potwar basin (so in Waziristan to the west, and in Tibet to the east) is the abundance of ostracods. Practically no work has hitherto been done on Indian fossil ostracods; but after identifying Bairdia subdeltoidea (Münster) in the Upper Ranikot beds at Thal, I found so many ostracods of other types appearing in washings of Ranikot clays from different parts of the Kohat-Potwar basin that I sent a considerable collection of them, besides ostracods from later Eocene beds, to Miss M.H. Latham for description. She noted the presence of nine species altogether, all of which are present in the Upper Ranikot but only two of which have yet been found in later Eocene beds. B. subdeltoidea is the commonest species at all levels; but the abundance of Cytherids - represented by seven species - in the Ranikot is very marked, and quite unlike anything seen in later Eocene beds of this region.
It will perhaps help those who cannot identify correctly foraminiferal species with confidence, to note that the presence of many ornamented ostracods in an Indian Eocene bed is an almost certain indication that that bed could be referred to the Ranikot. It may relieve the monotony with which certain geologists dismiss any Eocene formation they see as simply "nummular," a practice which a student of the Eocene, searching records for detailed observations to add to his own, finds somewhat exasperating. He considers that some effort should have been made to identify the stage, even if it is too much to expect that the zone should be recognised. The ting of the presence of ornamented ostracods would also be of more practical use than the habit of certain Indian geologists, when they think that certain calcareous rocks probably belong to the earlier Eocene, but shrink from referring them to a particular stage, of calling them "Hill limestones" at expression has no exact stratigraphic value, and merely (as I have indicated elsewhere) simulates definition while defining nothing.

The Patala Shales.

The sea appears to have become shallower again after Khairabad Limestone beds. The latest Ranikot deposits are best seen to the east - e.g. on the It and Kalachitta ranges. They have already been described on the former; and in the Nahrwali nullah section of the latter they consist of about 400 feet of shales and sandstones, with some thin calcareous bands. On both ranges their lower portions are highly fossiliferous, and their upper levels are so.

It seems significant that the Patala Shales of the Salt Range are generally darker in colour and more carbonaceous than those of the Kalachitta range. Ranikot coal beds are found in the western parts of the Salt Range (the borders of the Kohat district) and at Dandot further to the east. Ranikot coal beds are also found in Sind. It should be remembered, in this section, that the area between the Kohat-Potwar basin and the proto-Sarasati river (which I believe carried down the carbonaceous matter which formed the southern coal deposits) was an old land surface, and very different from a recently emerged lands to north and west. The carbonaceous deposits on the borders of the older land surface indicate that it supported considerably more vegetation than the newer lands on the opposite side of the Ranikot estuary.

The Nammal Shales.

Just as the Patala Shales constitute the latest known Ranikot element, do the Nammal Shales constitute the earliest known Laki element, of the Deccan of north-west India. The unconformity (elsewhere much more marked) between the Ranikot and the Laki, is there reduced to the smallest proportions yet found in the Indian Eocene. These two zones, taken together, probably represent the extent of the unconformity indicated by the "Basal Laki Laterite" of Nuttall's Sind sequence; for the is below that laterite are about equivalent in age to the late Khairabad limestone, while the Meting Limestone which succeeds the laterite corresponds approximately with the Sakesar Limestone of the Salt Range.

The earlier portions of the Nammal Shales are generally unfossiliferous, but the earliest fossiliferous zones contain in places an abnormally large mixture of Ranikot forms which do not survive to higher levels. The Laki
aracter of the deposits is, however, indicated by the appearance of such
tical European species as Assilina granulosa (well seen at Kalabagh, on
borders of the Kohat district), Nummulites atacticus and N.irregularis.
It clearly indicates that the segregation of Indian waters had come to an
; and the fact that local conditions suited the invading European species
indicated by the way in which they threw and supplanted many of the Ind-
tones.

The fact that geographical changes also occurred nearer at hand is sug-
ested by an alteration in the nature of the sediments, the Nammal Shales
being much lighter coloured than the Patala Shales. I suspect that this
is due to the advance of the Afghan coast nearer to India, at the commence-
ment of Laki times, as already noted. The increased elevation of northern
ghanistan, which produced that advance, would have tended to increase the
ount of drainage coming from the west, as well as bringing it nearer; and
it may account for the lighter colour and more barren nature of the depos-
ts.

Now reduced the extent of the Kohat-Potwar basin had temporarily be-
to the west, seems indicated by the limitation westwards of visible
mal Shales, which have only hitherto been found in the Salt Range and Tar-
bi sections in the eastern parts of the Kohat district. It is possible
nt these shales extend a little further to the west, but evidence of their
ng so has yet to be found. Owing to the approach of the Afghan coast in
lest Laki times, it is possible that the Patala Shales may have been de-
ited much further to the west than they are now found, and may have been
oved in early Laki times. We cannot therefore draw the same inference
m the eastward limitation of the Patala Shales as we can from that of the
mal Shales. The dark colour and regular sequence of the Patala Shales as
n on the Salt Range seem to me to guarantee that the Afghan coast remained
a distance throughout the period of their deposition. At the same time,
can infer that the Afghan coast moved eastwards at the commencement of the
mal Shales period both from the change in colour and the irregularity in
ents of the Nammal Shales themselves, as well as from their limitation
the west; for the subsequent deepening of the waters renders it less like
that Nammal Shales were removed from the west.

The later levels of the Nammal Shales merge, on the Salt Range, with the
er levels of the succeeding more calcareous formation, and it is often
dicult to say whether to attribute certain beds to the one or the other.

The Sakesar Limestone.

This formation is only found, so far as the Kohat district is concerned,
the Salt Range along its south-eastern border. It indicates a local deep-
ng of the Laki sea, and the corresponding westward movement of its westem
st. The fauna of the Sakesar Limestone differs little from that of the
mal Shales, except for the disappearance of some of the larger and proba-
more littoral forms like N.irregularis and Discocyclina ranikotensis, and
abundance of Alveolines, notably A.globosa which similarly abounds in the
Laki limestones of Sind and Baluchistan (known respectively as the Met-
and Dunghan Limestones). Its general facies seems, in fact, to agree
ny well with that of those limestones as recorded by Nuttall; and I have
found that the late Ranikot species N.bahirii, which survives through
Nammal Shales and probably extends into the lowest parts of the Sakesar
stone, appears in collections from the base of the Meting Limestone of
. I therefore provisionally correlate the Sakesar Limestone with the
Inghan and Meting Limestones, which are the lowest fossiliferous formations in the south.

I have not found any very definite representatives of the Sakesar Limestone further west in the Kohat district. Perhaps the water was not deep enough there to form such a limestone at the time, or the influence of the proto-Kurram river may have interfered with its development (the bed of that river having probably moved eastwards with the relative rise of land to the west). Some thin limestones, separated by shales, occur in the Pan-Tarkhobi area, between the local Nammal Shales and Shekhan Limestone, and these may represent the Sakesar Limestone; but it would be a very recondite representation.

The fact, however, that a considerable limestone like the Sakesar formation succeeds the Nammal Shales on the Salt Range itself, shows that the evaporation of the Salt Range axis had not begun when it was deposited. This did not have been until later Laki times that the Salt Range axis first began to rise.

**The Bhadrar Beds.**

This is a shallow-water series, which has hitherto only been found on the Salt Range. It indicates a local shallowing of marine waters, and is a last marine formation found on that range. It seems for the most part to be highly fossiliferous; but although its fauna distinctly approaches the Shekhan Limestone facies, it does not (as I showed in the Salt Range area) include some of the latest Laki elements which abound in the latter, and so appears to be of rather older date.

Dr. A. G. Brighton, curator of the Sedgwick Museum at Cambridge, kindly lent me cores of the borings from the Jhatla well, about 12 to 15 miles north of the Salt Range, on which Dr. Nuttall reported some years ago. I found that the uppermost layers of these, which Nuttall thought might belong to the Laki or the Khirthar, can best be correlated with the Shekhan Limestone. They are definitely pre-Khirthar, but uppermost Laki, containing admixture of Lockhartia tipperi (a Ranikot and Laki species, never yet found in the Khirthar) and Dictyconus-group forms which make their first appearance in the Shekhan Limestone, and for which I looked in vain among Salt Range collections. I also found that Shekhan Limestones constitute the uppermost Laki elements exposed in the Chor Galli section of the Khairimur Range, about 20 miles south-west of Rawalpindi. Thus the Shekhan Limestone undoubtedly developed to the north of the Salt Range; so its absence from Salt Range itself must either be due to its never having been deposited that locality, or to its having been removed subsequent to deposition, in line to the former opinion, because it is strange - if later beds had been deposited - that none should survive in any part of this extensive and much faulted range. The Bhadrar beds themselves have obviously been jected to denudation; and if they had been succeeded by a limestone, one would expect some fragments of the latter to survive as protecting caps to softer shales. It also appears that Gypsum and portions of Lower Chhar-beds locally overlap onto the Salt Range without any sign of the Shekhan Limestone appearing below them. This seems clearly to indicate a degree of emergence and denudation of the Salt Range in late Laki times.

It has been claimed that a considerable section of the Sakesar Limestone extends laterally into Gypsum, which is held to be a local facies of that
It seems incredible, however, that a local concentration sufficient to produce gypsum should have not only occurred but continued throughout Sakesar Limestone times, in the middle of an open sea which bounded with life on either side. I can imagine no circumstances capable of producing such a continuous as well as extraordinary local effect. It seems easier to explain matters by local action after Sakesar Limestone times. Flood-streams might dissolve out limestone, leaving holes in which the desiccating waters of subsequent marine invasions could deposit less soluble gypsum; and contact gypsification of the adjoining limestone might afterwards produce an appearance of lateral transition. provisionally regard some such explanation as accounting for the phenomena in question. In any case, the phenomena must be accounted for by something which happened within Eocene times, and before the later Khirthar; and the explanation here offered, which seems the most reasonable, postulates a degree of emergence of the Salt Range axis after the deposition of the beds.

Since the Bhadrar beds succeed a formation approximately correlated with the Meting and Dunghan Limestones of the south, and antedate a limestone approximately correlated with the "Laki" Limestone of Sind, I regard them as roughly contemporary with the Meting Shales of Sind and the lowest parts of the Ghazij Shales of Baluchistan (see correlations, Text-figure 6) although their connections cannot be continuously traced with either.

The Shekhan Limestone.

This limestone was first described in my paper on the geology of Kohat (1924) when dealing with the sequence exposed in the Shekhan nullah four miles east of Kohat; and although I gave it no name at the time (referring to it as beds "9" and "10" which I correlated with Vredenburg's "Alveolina limestone") it has since acquired the name "Shekhan Limestone" among geologists who have visited the section to which I drew attention. I do not know who first employed this term, which is nevertheless very suitable since there is probably no better exposure of the formation. It is certain that the term "Alveolina Limestone" must go. As Nuttall has shown, Vredenburg confused two very distinct formations under that name; and it is now with the later one - which Nuttall called the "Laki" Limestone - that the old beds "9" and "10" can best be correlated.

The Shekhan Limestone (as it is now called) is from 100 to 120 feet thick as regards its more calcareous portions, and sometimes up to 200 feet thick if we include large shaley intercalations. Outcrops of it appear among most exposures of Laki beds in the vicinity of Kohat, and are easily distinguished from Khirthar beds by their yellower colour, more nodular nature, and distinctive fossils - in particular Alveolina oblonga and the form which I called Assilina cf. pustulosa in my Salt Range paper but now describe as A. shekhanensis n.sp. Mollusca are fairly common, and often better developed than corresponding forms in the succeeding Kohat Shales. Arthropods are also common (a characteristic which this limestone shares with the "Laki" Limestone of Sind) and are often of large size; Conoclypeus irini Davies (related to C. stephaninii Dainelli, of Europe) appearing in any exposures. The general aspect of the fauna is rich. It seems to indicate that, although desiccation followed so soon afterwards, conditions of existence were very favourable to littoral forms just before it began.

Exposures of the Shekhan Limestone to east of the Indus show it to be...
more massive there than to the west. As already noted, it has been traced far as the Khairimurat range in the east, and is present under later \textit{teriary} deposits a few miles north of the Salt Range. When discussing the correlation of Pinfold's Chharat series (1926) I treated the limestone underlying the same as equivalent to the Shekhan Limestone (which I was then calling the "Alveolina" Limestone). I still think this correlation correct; but the relatively unfossiliferous nature of the limestone at Chharat is normal for the Shekhan Limestone, and I suspect that the difference is due fluviatile influence along the northern shore of the Kohat-Potwar basin that time.

It is certain that the north-western portion of the Himalayan axis had then risen, and it had probably completed severing the connections of the Kohat-Potwar basin with Tibet. It would follow that the drainage of a thousand miles of trans-Himalayan area, which had previously passed to sea via the long estuary, would be trying to find its way round the ds of the newly-risen obstacle. The portions of the ponded waters which und their way round the northern end of the obstacle would probably de-end, at first, in the form of a number of streams upon the northern shores the Kohat-Potwar basin (see Text-figure 4). That would presently tend make the waters adjoining that shore more brackish than the waters further south and south-west, and may account for the relative absence of for-infífera in the north-eastern aspect of this limestone. The early distrib-dnated nature of the descending streams might also account for no pronounced cal delta being found. Later on, however, after one of the streams had proceeded in deepening its bed more than the others, it might capture the hers or at least secure the greater part of the discharge from the or-inial source; and having well established its course, it might subse-ently maintain the same by continued cutting down across the axis of the ill rising Himalayas. This is how I would account for the origin of the per Indus valley (compare Text-figures 4 and 5), which passes northwards on the Kohat-Potwar basin, and curves round in a broad arc across the Hima-layan axis to find, and subsequently adhere to, the latest course of the trans-Himalayan Eocene sea, cutting three enormous gorges through the Ladak-hage in order to take that course. (I cannot attribute this phenomenon touple head-erosion by a tributary of a late "Indobrahm" river, as suggested Pascoe, or of Pilgrim's still later "Siwalik" river. In my opinion, the per Indus established its course before, not after, the lower Indus. The per Indus was in existence long before the lower Indus ceased to be an estuary.)

Discussion of Himalayan developments and the origin of the upper Indus seem remote from the Kohat district; but I cannot dissociate these ngs. The Kohat district forms half of the Kohat-Potwar basin, the inter-gological history of which is intimately related to events at either ed of the basin. It seems significant that Mr. E.R. Gee found a number of all fishes in shales intercalated with gypsum, immediately above the She-khan Limestone level, near Malgin (33°19'17''10°31'1''1) about 20 miles E.S.E. of hat; and although these fishes were described as estuarine forms by Dr. ider Lal Hora (1937), they are definitely regarded by Dr. E.I. White as long all undoubtedly freshwater forms (Cyprinoids, etc.). XX Dr. White kindly let me see his (unpublished) description of these forms. If the per Indus and Jhelum rivers had, as I think, established themselves by n (see Text-figure 4), freshwater fishes might well have been carried by n into and across the basin where fluviatile and marine conditions were ll struggling for ascendency. I cannot think that these fishes were bught by the proto-Kurram river, for they appear too far to the east.
In any case, whatever the explanation may be, the north-eastern facies of the Shekhan Limestone seems to be less fossiliferous than its facies elsewhere; and its eastern facies in general is more massive than its facies round Kohat. As it is traced westwards from Kohat, this limestone becomes progressively thinner and more shaley, and near the western borders of the Kohat district it appears only as a few calcareous and fossiliferous layers capping a considerable thickness of unfossiliferous shales whose base is not seen. What the age of these underlying shales may be it is difficult to say, owing to the recurrence of shales of identical aspect throughout the Cretaceous and most of the Eocene, north-west India. A few miles to the east of Thal, the last traces of Shekhan Limestone fossils disappear; yet the shales seem to continue as if and to south of Thal they are capped by calcareous layers with fossil fossils. The phenomenon is disconcerting, but unmistakable. It is impossible, apart from the cappings of fossils of very different age, to distinguish between the underlying shales, which seem to be continuous regardless of cappings.

The reduction in thickness of the Shekhan Limestone to the west, and the absence of recognisable Lower Laki elements, indicates the shallowing of the Laki basin. If denudation removed later Ranikot elements to the east, while similar shales were still laid down to the east, Laki fossils seem to succeed the same beds to the east as Ranikot fossils succeed the west.

These appearances originally deceived myself, for when describing the Ranikot beds at Thal (1927) I showed what I took to be "Meting Shales" marked "j - j" on Fig. 8, opposite p. 286) overlying the fossiliferous Ranikot beds (marked "e - e"). They were exactly like Laki shales which I had seen elsewhere, and I suspected nothing, being engaged on proving the Ranikot age of the underlying beds. At my last (1935-1936) visit, however, I found that some very thin calcareous layers immediately underlying bed - k" (which is really of Khirthar age, not Laki) were full of fossil fossils. In fact, there was no Laki there at all, the Khirthar overlying rectly onto the Ranikot. And yet my continuous mapping had just proved at true Laki beds, of exactly similar aspect to these supposed "Meting shales", approached within a few miles of this very section.

It was after this that I pointed out (C.R.S.S. Soc. géol. Fr., 1936) in position to Dr. A.M. Heron, that fossil evidence must be found above Waziristan shales can be safely attributed to the Laki.

**The Passage-Beds, Petroleum, Gypsum and Salt.**

Mr. E.S. Pinfold and Sir E. Pascoe have dealt the most fully with the section of the sources of oil in the Punjab, and seem to agree that the productive horizon is at or near the level of the "passage-beds" at the base of the Lower Chharat. Mr. Pinfold showed me the type section for these beds Chor Galli, on the Khairimurat range. The Upper Chharat is there missing; and Murree beds overlap onto rather over 200 feet of Lower Chharat, which conformably succeed about 230 feet of "passage-beds", which in turn conformably follow the Shekhan Limestone.

About two-thirds of the passage-beds in this section consist of limestones, which vary from a few feet up to 30 or 40 feet in thickness, and alternate with shales throughout the series. The lowest limestones are mass-
The intermediate ones flaggy and the upper ones marly. All these beds, where derived fossils and rolled rock fragments form a "Fateh-Jang" are crowded with minute fissures at right angles to the bedding. These fissures are filled with calcite and gypsum which, being less soluble than the matrix, stand out on weathering and give the rock a very stringy appearance. Pale yellow to grey colours characterise both the limestones and shales of the series, yellow tints predominating in the upper beds and red-brown those of the lower ones. The only unconformity in the series appears at the base of the Murree beds, where derived fossils and rolled rock fragments form a "Fateh-Jang". The only gypsum in the section appears in the fissures of the passage-bed limestones, besides a few traces in the Lower Chharat shales.

Gypsum is, indeed, very little seen to the east of the Indus, if we except the gypsum and salt of the Salt Range itself. I do not propose to discuss the Salt Range gypsum etc. here, because it is in a faulted and anomalous position, if it be of Tertiary age.

Gypsum and salt (apart from the Salt Range) are much better developed to the east of the Indus, and may be said to appear over a belt which is about 20 miles broad at its western end (from a little south of Latamber to rather north of Gurguri) and runs east-north-east from there to the Indus. Both salt and gypsum are very variable in amount, but the larger quantities appear in the southern and south-western parts of the belt. Their distributions are best seen on Wynne's map of the southern portion of the Kohat district, for only some of the northern fringe of the belt enters the portion the district mapped by myself. Gypsum is much more commonly seen than salt (as Wynne's map shows); and this is what might be expected, owing to the much greater solubility of the salt. In all cases known to me, the salt underlies the gypsum; and I never saw the base of the salt, its contact with adjacent beds being always either hidden or faulted.

The base of the gypsum, however, where not connected with salt, was often-seen; and with singular consistency it appeared to be at or about the horizon as the base of the passage-beds. Thus from Daud Khel village (near Shadi Khel) for about a mile to the west, there is a series of gypsum tufles, measuring from about 4 to nearly 100 feet in thickness, which sometimes lie on small quantities of passage-bed limestones, and in other cases have thin seams of such limestones interstratified with them. In all these cases, Shekhan Limestones and shales form the base of the series, and Lower Chharat beds succeed the gypsum. Similarly at Panoa, where the gypsum is on 60 to 150 feet thick, it is underlain by 25 feet of passage-beds, which are of Shekhan Limestones; while above the Gypsum come 300 feet of Lower Chharat beds.

In these cases, as in others, the passage-beds are very reduced in quantity, and the gypsum either immediately succeeds them or is interstratified with them and survives them. That the gypsum continues into Lower Chharat shales, is occasionally seen by its interstratification with Lower Chharat beds. This is well evidenced at Tarkhobi, where the top of the Shekhan Limestone seems to be marked by a 2-ft. Ostrea band, succeeded by 25 to 30 ft of green and yellow, sometimes sandy, shales and limestone bands, the latter parts of which become gypsiferous, while some of the limestones are of passage-bed type. After that come the following:
Gypsum . . . 38 feet.
Red shales . . . 70 "
Gypsum . . . 10 "
Red shales . . . 45 "
Gypsum . . . 2 "
Red shales . . . 30 "
Gypsum . . . 1/2 "
Red shales . . . 80 "
\[ \text{275 feet} \]

In every case that I saw during my last general survey, the large masses of gypsum of the Kohat district lay at the same horizon, i.e., above the Shekhan Limestone, and were either interstratified with or below the succeeding beds at Chharat. Thus they were either in, or both in and slightly above, the strata occupied by the passage-beds. The most western gypsum lenticles at I found appeared in an outcrop a mile or so north and north-west of the Anarchina village (\(33^\circ22_{2}^{1} 71^\circ1_{2}^{1} \))", they were from 30 to 50 feet in thickness, and similarly lay between Shekhan Limestone beds and succeeding Chharat ones.

I have therefore abandoned my earlier opinion (1929) that the main period of deposition of the salt and gypsum was between the Ranikot and the Miranzai. I now believe that it was at the close of the Laki. It was not dissipated from, but immediately preceded and led up to, the fluviatile Lower Chharat phase in the same area.

It seems to be worth noting that the passage-beds are best developed to the east of the Indus, while the main gypsum deposits are to the west of it river. Gypsum deposits and passage-beds overlap to some extent the north-eastern parts of the Kohat district. It may be significant that, if we ignore the faulted and abnormal Salt Range area, the oil seeps etc., shown on Sir E. Pascoe's map seem to be mainly distributed over the region where the passage-beds appear; and certainly the main oil wells are to the east of the Indus, where those beds are thickest. On the other hand, the region where the gypsum and salt are best developed is the one where dicic marine incursions from the south would have brought fresh salt waters to be desiccated out; and the fact that the gypsum does not extend farther to the east may indicate that the influx of fresh waters (probably from the upper Indus and Jhelum rivers) prevented desiccation from becoming complete in the deeper eastern parts of the Kohat-Potwar basin of the time. Any case, the passage-beds seem to represent the product of conditions developed in the eastern parts of the Kohat-Potwar basin at that time; those conditions were apparently the most favourable for the production of oil.

**The Lower Chharat beds.**

Although passage-beds exist in the Panoba-Tarkhobi exposure some 30 miles east of Kohat, and small quantities near Shadi Khel about 10 miles south of at, I saw none either round Kohat itself or in the Miranzai valley to the east. The northern parts of the Kohat district (except to the east) show traces either of passage-beds or of gypsum, the Lower Chharat beds of se parts immediately succeeding the Shekhan Limestone.

The upper levels of the Shekhan Limestone in these north-western parts the Kohat district assume a definitely shallow-water facies, calcareous shales and grits appearing in them, often accompanied by an Ostrea-bank.
the other hand, the succeeding Lower Chharat beds of these parts often contain Laki foraminifera in their lowest levels; so the sequence appears to be perfectly conformable.

It is interesting to note the changes in the character of the Lower Chharat beds. To east of the Indus - on the Khairimurat range and at Laki itself - they are represented by variegated shales and limestones; the latter are sometimes crowded with Planorbis, while the former contain casional Cheloniian plates and reptilian bones. In the southern and eastern parts of the Kohat district the Lower Chharat is principally presented by dark red shales, with occasional pisolithic bands of the same colour. These red beds compose what Wynne called the "Red Clay Zone" in descriptions of the southern parts of the Kohat district. They are distinguishable in colour etc., from some of the succeeding Murree beds of Ch Late age; and in one case at least Wynne mapped Murree beds as Eocene mistake. (This was on the extreme north of his map, longitude 71°11', but a mile south of "Wulalai" village. I went over the actual spot, and found no Eocene outcrop.)

Near Kohat itself (also at Bahadur Khel, and in other south-western positions) red sandstones make their appearance among the red shales. Reptilian bones occasionally appear, as to the east of the Indus. Further east, however, in the lower Miranzai valley and adjoining valleys immediately south of it, dark brown to black grits begin to be seen at the base of lower Chharats, forming a well-marked horizon. These sandstone and grit beds increase in thickness and number to the west, and soon become interspersed with thin conglomeratic layers. The conglomerates in turn become thicker and more numerous, as traced to the west; and although they are at first black to rusty in colour, they afterwards (i.e. further to the west) assume a very characteristic yellowish-brown appearance, with highly calcareous matrix, and usually emit a porcellaneous ring when struck with a hammer.

They are quite unlike later Tertiary conglomerates of the same region, and are easily distinguished from them even at a distance by reason of their duller colour. Their contents are equally characteristic, consisting for the most part of cherty white and pink pebbles - probably from the "Parh" of Cretaceous beds to north-west and west; but they also often contain limestones pebbles of Cretaceous, Ranikot and Laki age. Round Hangu these limestones are sometimes 8 or 9 inches in diameter; further west they are sometimes still bigger, although most of the pebbles are always much smaller.

Shales separating the conglomerates and sandstones still generally retain their red aspect, although the lower shales are often yellow in colour; the underlying Shekhan shales; but in spite of the progressive coarsening of the formation to the west, its total thickness decreases. Round Kohat to the east of Kohat (Panoba, etc.) the Lower Chharat is about 300 feet thick (locally varying from 250 to 350 feet); near Hangu its thickness is often only about 50 feet. After that it still decreases down to a dozen feet or less, until near Sarozai the formation suddenly expands to a great thickness of sandstones, conglomerates and shales. The conglomerates are of typical Lower Chharat type, and sections of the sandstones with Laki foraminifera and a proportion of wind-rounded sand grains. I could measure the formation, owing to the faulted and disturbed nature of the series seen; but its thickness could hardly be less than 400 or 500 feet, might be much more. This thickness is local, however, extending only a few miles to the west (the whole visible outcrop covers about 12 miles), after which the formation rapidly decreases again in size, is only 4 to 8 feet thick near Dallan, and finally disappears near Thal, little beyond the last apparent traces of the Shekhan Limestone.
This great local development of the Lower Chharat sandstones and con- 
comerates near Sarozai suggests a river deposit — probably a delta — and 
would identify that river with the proto-Kurram river whose Ranikot delta 
pears at Thal. The displacement of the delta some 15 miles to the east 
Lower Chharat times seems to be correlated with the emergence of northern 
ghanistan at the close of the Ranikot, and the consequent eastward mov- 
ent of the Afghan shore-line. The raising of contours to the west would 
nd to force the river to take a more eastern route; and in adopting that 
ut, the river would wear through what were then the most recent rocks 
ere Cretaceous and early Eocene) as its contents seem to indicate.

The Kohat Shales.

I called this formation the "Kohat Shales" (1924) after its development 
and Kohat. It is really the lower member of Pinfold's Upper Chharat ser-
es, and represents the return to marine conditions after the Lower Chharat 
viatile interlude.

Although nearly the whole of the Lower Chharat formation near Kohat is 
a dark red colour, its uppermost layers assume purple tints, conclu- 
ing about 6 feet of mauve to indigo-coloured shales, which are succeeded 
about 2 feet of light grey limestone full of Planorbis. After this come 
3 feet of unfossiliferous shales and thin concretionary limestones, 
ollowed by another 2 or 3 feet of grey shales with thin limestones contain-
foraminifera; after which comes a calcareous band packed with small cys-
er-s and megalospheric Assilines (Am. subpapillata). Thus the change from 
viatile to marine conditions is fairly abrupt; but there seems to be 
ittle if any unconformity. Both the Planorbis band and the Upper band 
e be seen in most exposures round Kohat; but the junction of Lower and 
er Chharat beds is also often marked by a prominent light-coloured band 
hard cherty limestone, from 4 to 8 feet thick, which seems to take the 
ace of the few feet of intervening shales and concretionary lime-
ones.

Following the Ostrea band comes a succession of light-coloured shales 
llowish to east of the Indus, greenish-grey to west) alternating with a 
er of thin limestone bands. The limestones are thickest and most 
wed about the middle of the sequence, where two or three bands from 4 
6 feet thick usually appear close together, with many molluscan casts 
quenting the thin shales between them. The uppermost levels of the Ko-
Shales afford the richest horizon for N. laevigatus and N. carteri, and 
to merge with perfect conformity into the succeeding Nummulite Shale.

The total thickness of the Kohat Shale is about 45 to 50 feet at most 
the Chharat area. I examined the type section in the Bhagwan Kas nullah 
detail, paying several visits to it, and found that Mr. Pinfold's estim- 
of 100 to 200 feet for this formation there is far too great, the beds 
ing much faulted and repeated. The thickness of the formation increases, 
ever, as it is traced to the west, being about 60 feet at Panoba, in the 
ern parts of the Kohat district, and 85 to 90 feet round Kohat itself. 
then generally decreases in thickness to south-west and west; being about 
feet at Bahadur Khel, 50 feet at Latambar, and 30 feet at Thal. As Mr. 
fold remarked, the formation is not very fossiliferous near Chharat (al-
ugh the fossils that do appear are of the same types as elsewhere); its 
ern outcrops are much more fossiliferous. This may be due to the more 
ckish nature of conditions to the north-east, if the early upper Indus 
Jhelum rivers were discharging there as I suspect (see Text-figure 5).
I originally (1924, 1926 etc.) regarded the Kohat Shale as a transi-
tional bed between the Laki and the Khirthar. That was because the Palae-
tologist at Calcutta, on whom I depended for foraminiferal identifications,
before I knew much about the subject myself, reported finding Assilina gran-
osa, N. atacicus and Alv. oblonga in my collections from near the base of
own work on these forms has since shown that the supposed A. grana-
sa is really A. subpapillata, and the supposed Alv. oblonga are young Alv. javana.
It has also shown that N. atacicus survives far into the
Khirthar instead of being confined to the Laki as thought by Vredenburg.
N. perforatus I would now prefer to call N. uroniensis. I therefore now
say the whole of the Kohat Shale not only to the Khirthar but to the low-
portions of the Middle Khirthar, and regard the Lower Chharat beds as
relating not with the Ghazij Shales as I formerly supposed (1924) but
with the Lower Khirthar.

Conspicuous among the Kohat Shale forms are Dictyococ空ides kohaticus,
velina javana, Alv. violae and a Nummulite allied to N. beaumonti but
ller, and with rather excavated pustules at the poles. This was called
amondi in my early papers, and has been referred to N. beaumonti by other
ologists; but it certainly is not N. beaumonti s. str., and I now regard it
a new species and redescribe it as N. pinfoldi. It may be a premutation
the true N. beaumonti, which appears at a higher level both in India and
Europe. N. pinfoldi is one of the commonest and most constant species
in the Kohat Shale, but I have never yet seen it at any other level.
e the true D. kohaticus it is, locally at least, a zone fossil for the
Shale.

The Nummulite Shale.

This is the upper element of Pinfold's Upper Chharat series, and was so-
ed by Pinfold because of its aspect in the type area (Bhagwan Kas nullah,
r Chharat) where it is composed of masses of loosely compacted foramin-
a. Assilines are very common in it, being chiefly represented by A. pap-
ata and A. exponens with their megalospheric companions. N. atacicus and
loniensis are also common; and towards the top - which becomes very ar-
laceous and in places almost a pure clay - many Discocyclina dispersa
ear. Faulting and duplication greatly increase the apparent thickness
this formation which, so far as I could judge, is only about 100 feet
in the Bhagwan Kas nullah. Pinfold, who stated that it varies from
200 feet in thickness, figured it as measuring about 200 feet in that
ion. I therefore - judging from that section - doubt if it ever meas-
s much more than 100 feet to east of the Indus. I never, myself, saw it
in much greater thickness anywhere.

In the Panoba section, a little west of the Indus, I found the Nummulite
le to be about 60 feet thick. Alv. violae appear in it there, as also in
underlying Kohat Shale of that section.

In the Shekhan nullah near Kohat this formation, although much more com-
ted than to the east of the Indus, is still quite distinct from the mass-
limestones which succeed it, and is 120 feet thick. Nummulites there
ominate over Assilines, although the species themselves remain much the
as to the east. Alv. violae also appears, though less commonly than in
parts of the Kohat district. I saw no Discocyclina dispersa in the
district. Its abundance in the highest and most argilaceous portion
the Nummulite Shale at Chharat may either indicate a preference for shallow-water conditions, or tend to correlate that portion of the eastern Nummulite Shale with a later horizon to the west. (In any case it seems significant, with reference to the shape of the Kohat-Potwar basin at that time, that the Nummulite Shale to the east is capped by clays, while to the west it is succeeded by massive limestones.)

In the western parts of the Kohat district the Nummulite Shale becomes still more calcareous. It is sometimes indistinguishable from the succeeding limestones, except for the greater abundance and crowding of its fossils; at other times it is flaggy or nodular, and interspersed with clays or clays. Round Thal it is very variable; but I could still rather distinctly recognise it as consisting of about 40 to 45 feet of rather grey to flaggy grey limestones, with Alveolina and abundant Dictyococnoides pumpliformes. Its fauna there is mainly distinguished from that of the underlying Kohat Shales by the absence of Dictyococnoides kohaticus and Pinfoldi, both of which abound below it.

One of the main differences between the Nummulite Shale and Kohat Shale is that most exposures of Upper Chharat beds, is found in the relative abundance of molluscan casts in the Kohat Shale, and the absence of all molluscan remains in the Nummulite Shale except for a large Pycnodont and a small Pec.

I have never seen this Pycnodont (which is very like Ostrea vesicularis) at any other level in the Kohat Eocene; but it appears in Nummulite outcrops all over the Kohat-Potwar basin, and at the corresponding horizon in Baluchistan etc. far to the south.

**The Kohat Limestones.**

Succeeding the Nummulite Shale in the Kohat district comes a considerable thickness of limestones, roughly divisible into two portions which I propose to call, respectively, the Lower and Upper Kohat Limestones.

These beds have not previously been given separate treatment by any author. They, together with the underlying Nummulite Shale, were described "Nummulitic" and "Alveolina" limestones by Wynne (1875, etc.) when dealing with what he called the "Nummulitic series" (which included the Kohat district) of the southern parts of the Kohat district. Pinfold's subsequent description of the lower elements (Nummulite and Kohat Shales) of that series, as seen to the east of the Indus, under the designation of "Upper Chharat" beds, necessitates the separate treatment of those later elements of Wynne's "Nummulitic series" which are seen to the west of the Indus, as the name "Kohat Limestones" which I propose to attach to them, indicating both their more calcareous nature and their especially fine development in the Kohat district.

The Lower Kohat Limestone is a massive fine-grained one, light to dark grey in colour. It is particularly well seen in the Shekhan nullah, where it is about 120 feet thick, and divisible into three parts. Its lowest 10 feet are transitional from the Nummulite Shale, slightly shaley to flaggy in place, and crowded with foraminifera; the next 55 feet are of grey colour and massive in type, with fossils less crowded and weathering out only in patches; the uppermost 55 feet are of lighter grey colour, still massive in place, and with still fewer fossils showing.

The Upper Kohat Limestone is only about 50 feet in thickness, but is clearly distinct, being a hard yellowish limestone which, although not very...
cular in the Shekhan section, is often distinctly nodular elsewhere. In st cases it is full of globular Alveolines and contains many Orbitolites planatus.

Thus the total thickness of the Kohat Limestones is about 150 feet near hat. If the 120 feet of Nummulite Shale be added to this, it makes a to-1 of nearly 300 feet of Khirthar limestones. Adding the 85 feet of Kohat ale makes a total of over 375 feet of marine Khirthar beds, excluding the rki Shales which would bring the total up to a little more than 400 feet. we add the 200 to 300 feet of Lower Chharat beds, it makes a grand total between 600 and 700 feet of Khirthar rocks, of which about the lower two fths are fluviatile.

Near Thal, the lower grey limestone is about 15 to 20 feet thick, while e upper yellow limestone - which probably indicates shallower water - ries from 30 to 50 feet in thickness.

The lower and grey-coloured section of the Kohat Limestones is, on the ole, less fossiliferous than either the Nummulite Shale below it or the illowish and nodular (yet very hard) limestone which succeeds it. This st, and uppermost, section of the Kohat Limestones usually offers a very stinctive appearance in the field; its rather livid yellowish appearance king it recognisable from great distances, as it caps successive anticlines from which the later but softer Tertiary sandstones and shales have en removed. It thus often indicates the outcropping of Eocene beds long ore they are reached.

Not knowing the details of the local succession, which are best devel- in the northern parts of the Kohat district, Wynne greatly overestimated e total thickness of the Eocene beds which he saw in the Miranzai valley, nce he failed to recognise the fact when the same sequence repeated or versed itself in faulted or successive anticlinal and synclinal sections, d so added the whole together. I have prepared two sections, correspond- to the two shown by Wynne in his short paper describing this area, in der to indicate the true nature of the sequence which he largely misin- preted. (I wish to emphasise again, however, that I have the greatest miration for the consistency and thoroughness of Wynne's work whenever had the chance of being thorough, as when dealing with the southern rts of the Kohat district. Considering the handicaps under which he boured, and the very short duration of his visit to the northern parts the Kohat district in which myself lived for years, it is not surpris- g that I cannot always agree with what was really his record of first pressures.)

The Sirki Shales.

As already stated, I found these shales capping the Upper Kohat Lime- one in a number of synclinal valleys to east, south and south-west of Mgu; the village of Sirki Pela (33°27':71°04") occupying a fairly central sition as regards the exposures. I therefore propose to call these the rki Shales. None of the exposures show a great thickness of beds; the al amount being from 2 to 6 feet, and the largest one that I saw from to 30 feet in thickness. These beds should not be confused with the atch Jang" zone, consisting of pebbles and fossils derived from older cene levels, which often appears at what seems to be the same horizon,
Some exposures of the Sirki Shales are closely packed with Assilines, and might be styled an Assiline shale. These Assilines are distinguishable from those of lower beds, being a well marked variant of *A. papillata*. I am describing it as *A. rota*. I first saw this form in the upper levels of the Khirthar limestones at Spin Tangi in Baluchistan (the type area for the Khirthar), where it is similarly abundant and accompanied by a variant *Dictyococnoides kohaticus* which I described (1926) as var. *spintangiensis*. *Kohaticus* has not been found by me above the level of the Kohat Shales where in the Kohat-Potwar basin; it seems to be absent both from the Nummulite Shale and from the Kohat Limestones; but I did find *D. kohaticus* var. *spintangiensis* in considerable numbers in some exposures of the Sirki Shales; it accompanies *A. rota* just as it does at Spin Tangi. This again indicates that the fauna of the Sirki Shales is not derived from lower levels, but is best correlated with the Upper Khirthar of Baluchistan. Another form which is very common in the Sirki Shales, but found at no lower level (so far as I saw) in the Kohat district, is *Alveolina elliptica*. Nearly all the echinoids that I found in those shales seemed to be of that species, which in indicates that the fauna is not derived from lower levels. The near-species to *A. elliptica* is *A. javana*, which is very common in the Kohat Shales; but I never saw *A. elliptica* in the Kohat Shales.

Thus the Sirki Shales are characterised by at least three well-marked forms (belonging to three different genera) which are at least variably distinct from, and yet related to, species found in the underlying Middle Khirthar beds; and the identity of two of these forms with ones peculiar as far as I have seen) to the Upper Khirthar beds of Baluchistan justifies a provisional attribution of the Sirki Shales to the Upper Khirthar.

Other forms in the Sirki Shales are *Orbitolites complanatus*, a small ten very similar to the one seen in the Nummulite Shale below, a number of small regular echinoids, and *Gythereis bowerbanki*—an ostracod which is in the immediately preceding limestones, and no doubt indicates a form of estuarine conditions to this area just before the sea finally filled from it.


This concludes the list of Eocene beds of the Kohat district. Later beds than Khirthar have not been found in this region. Indeed there is a stratigraphic gap (so far as fossils are concerned) from the Upper Khirthar to the Lower Murree (*i.e.*, from late Lutetian or Auversian to early Aquitanian). This gap is, to my mind, the most puzzling feature about the geology of north-west India. Conditions during the interval are not easy to visualise. I can only suppose that the Kohat-Potwar basin became a lake, in which the early upper Kurram, upper Indus and upper Jhelum rivers ended, while the overflow passed down the old channel connecting that basin in the sea to the south. If rainfall was scanty, and the northern areas were not very elevated, sediments in the basin might only have accumulated slowly; such organic remains as there were being destroyed before they could be buried, and oxidation being carried to considerable lengths...
There seems, however, to have been little deformation of the Kohat-Potwar basin itself until long after the Eocene. The succeeding deposits, from Murree to Nagri times inclusive, appear to conform as regards stratification very fairly well with the underlying Eocene; such differences of p., etc., as I saw indicating no great degree of distortion of the older strata. There is, however, a progressive overlap by later post-Eocene beds in the west, Kamlial (Helvetian), Chinjis (Tortonian) and Nagris (late-Eocene or Pliocene) successively overstepping onto the Eocene to the west Hangu. The Chinjis, which appear as the lowest post-Khirchar formation at Thal, there contain numerous pebbles, which I did not notice in beds of the same formation further to the east, and may indicate the influence of the early Kurram river.

Although, however, the approximate conformity in dip between Eocene and later ones seem to indicate that no great deformation of the Kohat-Potwar basin took place until the Pliocene, much deformation must then have occurred - indeed, the main present orogeny of the Kohat district must have been acquired - for Pleistocene terraces in the Miranzai valley and in valleys to east and west of the Miranzai still retain their approximate horizontality, and are inclined at much the same angles as recent deposits are the outcrops of older beds forming the present orogenic features of the district. On one of these terraces, about 50 feet above the present level of the Kurram river in northern Waziristan, I found an early palaeolithic element similar to ones recently discovered in the Soan syncline. In the lower Miranzai valley, thick Pleistocene conglomerates cap isolated hills in the middle of the valley, and overlie the upturned edges of almost vertical Murree beds.

It is now well known that great changes have taken place to east and west at the close of Pleistocene times; but although it is fairly common to find isolated masses of Pleistocene beds faulted into abnormal positions in the northern parts of the Kohat district, the general evidence there indicates that Pleistocene beds have not been much disturbed as a whole. In south-eastern parts of the Kohat district, however, there probably was considerable disturbance in sub-recent times. Pleistocene conglomerates of the Salt Range near Kalabagh. The very survival up to the present of large exposures of such a soluble mineral as salt, itself indicates that the same cannot have been exposed for any great geological interval. This also applies, of course, to the Salt deposits at Bahadur etc.; and it is noticeable that the Kamlial and Chinji beds near Bahakhel are tilted at extreme angles, and covered by recent deposits only in the valleys. I therefore suspect that although the main orogeny of the Kohat district was acquired in the Pliocene - perhaps the early Pliocene there was an increase of the thrusting from north and west respectively east and south of Thal, at the end of the Pleistocene or early in recent times. This may not have caused much distortion (though it probably increased the overthrusting) on the northern and western borders of the Kohat district; but I believe that the convergence of effects, through the Kohat district, on the south-eastern portion of the district, increased the distortion and faulting in that region, with the consequent exposing of fresh masses of salt which are still to be seen in large quantities between Bahakhel and the western Salt Range.

Another effect of this subrecent disturbance (which probably coincided
The elevation of the Pir Panjal range and the origin of the Sutlej (or Panjal) was probably the formation of the slight watershed which now divides the Kohat district and prevents any considerable river passing through it; the quantities of Pleistocene conglomerates in the Miranwali valley seem to indicate that a much larger river traversed it in early Quaternary times in any found in it now. It would be natural, as the post-Bajocian Indus which occupied the Kohat-Potwar basin filled up with sediments, for the upper Indus and upper Jhelum rivers to pass down that basin from east to west, join the upper Kurram river near Thal, and thence flow southwards as combined stream along the course of the old lower estuary connecting the two with the open sea. I suspect that when the late Pleistocene disturbance took place, the Kohat district to some extent, ring a watershed traverse it from the Salt Range to the Samana, but also raised the relief and foldings of the western parts of the Salt Range itself and so blocked the course of the combined river south of Thal. The result of that would be to turn the Kohat-Potwar region again into a lake, with overflows at various points on the crest of the Salt Range cut their channels back through that range, draining the lake and establishing new courses for the respective lower waters of the three main upper rivers. The Indus found its new channel across the Salt Range at Kalabagh, and was then lower down by the Kurram river after the latter had cut through the Salt Range opposite Mianwali.

7. Palaeontology.

Descriptions of a considerable number of Eocene foraminifera, and of a Eocene echinoids, of the Kohat district are to be found in my published works. Descriptions of Eocene molluscs, corals, ostracods etc. which I collected in the Kohat district, have been given by Prof. J.W. Gregory, Mr. Cox and Miss M.H. Latham. My work in connection with the present thesis the results of which I hope also to publish in due course - has been divided between (a) mapping the geologically unsurveyed parts of the district (comprising nearly a thousand square miles of hill country) attempting to reconstruct the Eocene history of the region (which has been attempted, since nobody has ever before zoned out the Indian Eocene in a manner to allow of such a reconstruction), and (b) work systematically through the fossil collections made during my last Indian visit, in order to confirm or correct previously published descriptions, and deal with any new forms appearing in the collections.

To describe, here, all the species on which I have recently worked, I should make this paper very unwieldy to little purpose. In most cases, I only confirm former descriptions, or amend them in minor respects. I propose only to deal with the more important new species, and those species which either require to be re-examined for comparative purposes, or need re-description because their significance demands fuller treatment than they have hitherto received.

The principal species in the latter class is *N. beaumonti*, D'Archiac and me, although it is a form which I have not yet found in the Kohat district. It is nevertheless important for two reasons: (1) It is common in uppermost levels of the Spin Tangi section of the "Spintangi" beds of southwestern Pakistan, and so helps to correlate those beds with the Upper Eocene beds of Europe - a correlation which has never before
been established in regard to any Indian Eocene beds; - and (2) N. beaumonti has never before been adequately fixed, by reference to the original material, with the result that Middle Eocene forms of India have been repeatedly identified with it, while true representatives of the species - both on the Indian continent and further east - have either been only doubtfully identified with it or (more commonly) referred to other species.

Several of the forms accompanying N. beaumonti in the type section at Tangi also appear in the latest beds (the Sirki Shales) only, of the Kohat district; and one of these forms is an Assilina (A. rota) which is not hitherto been described. So I describe it, as well as re-describing an earlier form (A. papillata Nuttall) of which it may represent a mutation.

I also describe a new species of Nummulite (N. pinnfoldi) which, in spite of its distinctive external appearance, may be a premutation of N. beaumonti, is valuable as a zone fossil for the Kohat Shale. Whether or not it existed before and/or after Kohat Shale times, I cannot say. It probably did. But the conditions of Kohat Shale times seem to have suited it so well, as compared with the conditions of other times, that its appearance anywhere in N.W. India is good evidence that that outcrop should be referred to the Kohat Shale.

Another new species, Assilina shekhanensis, and its companion A. subshekhanensis, are important as characterising Upper Laki beds.

Assilina tattaensis (d'Arch. & Haime) is redescribed, owing to the imperfection of its original treatment, its subsequent neglect and misidentification with A. granulosa, and my recent discovery of its existence in the Kohat district.

Two distinctive Ranikot Alveolines are dealt with, also a new Ranikot cocycline and its megalospheric companion.

The appearance of Alv. violae Checchia-Rispoli is recorded for the first time in India, and its representatives described as they appear in the upper Chharat (Middle Khirthar) formation of the Kohat district, which corresponds with the horizon at which the species appears in Europe.

It may be interesting to note, with reference to the new horizon (the Sirki Shales) found in the Kohat district, that the fauna of the Spintangi district (Vredenburg's "Upper Khirthar") with which Nuttall did not deal, and in which Vredenburg (1906, etc.) only quoted N. complanatus as a distinctive species (the others cited by him being either doubtfully identified or also at lower levels), was found by me to include the following more important forms:

Nummulites complanatus Lamarck. At the very top of the Spin Tangi (= "White Gorge" or "White Pass") section. The specimens found by me are poorly preserved, but seem to agree closely as to size, number of whorls, numbers and shape of chambers etc., with Fig. 2, Plate I, of d'Archias and Haime's monograph.

N. beaumonti d'Arch. & Haime. In the uppermost layers only, of the Spin Tangi section.

Assilina rota n. sp. In the upper layers of the Spin Tangi section.
It first appears below the level of \textit{N.}beaumonti.

\textit{Dictyoconoides} kohaticus (Davies) var.\textit{spintangiensis} Davies. This accompanies \textit{A.}rota at Spin Tangi. Upper levels of the section.

\textit{Alveolina} elliptica (Sowerby). Upper layers of the Spin Tangi section. According to Nuttall (1926) \textit{Alv.}elliptica characterises the Middle Khirthar. I suspect that the exposures in which he found it really belong to a later horizon. I never found it myself in true Middle Khirthar beds anywhere in the N.W. frontier of India, from Baluchistan to the Kohat-Potwar basin. On the other hand it is a constant companion, from Baluchistan to Kohat, of \textit{N.}beaumonti and/or \textit{Ass.}rota and \textit{D.}kohaticus var.\textit{spintangiensis}; and it similarly accompanies \textit{N.}beaumonti both in Assam and in the Dutch East Indies (e.g., Soemba).

To the best of my belief, on the evidence as it stands at present, the pre-quoted five forms all characterise the late Khirthar deposits of India, which are probably equivalent to the Auversian of Europe and may possibly extend into the Bartonian.

This serves to fill the gap at present existing between the Middle Khirthar (definitely Lutetian) beds of India, whose fauna was most fully described by Nuttall, and the Oligocene beds of Baluchistan etc., with \textit{N.}termedius \textit{d'Archiac} and \textit{N.}clipeus Nuttall, which were noted by both Edenburg and Nuttall.

\begin{verbatim}
Nummulites\textit{beaumonti} d'Archiac & Haime.

(Figures 1 to 8)


1883. \textit{Nummulites} Beaumonti d'Arch. & Haime; De la Harpe, "Monographie der in Agypten und der libyschen Wüste verkommenen Nummuliten", Palaeontographica, XXX, pp.180-182; Pl.XXI, figs.37-47.

1902. \textit{Hantkenia} Beaumonti (d'Arch. & Haime); Prever, "Le Nummuliti della Forca di Presta, nell' Appenino Centrale e dei dintorni di Potenza nell' Appenino meridionale", Mem. Soc. Pal. Suisse, XXIX, p.95; Pl.IV, fig.40.

\end{verbatim}
In the uppermost levels of the Khirthar limestones at Spin Tangi (55°68'08"), in the type area for the Upper Khirthar, and accompanied by Nummulites atacicus Leymerie var. Beaumonti d'Arch. & Haime; Cuvillier, "Révision du Nummulitique égyptien", Mém. Institut d'Égypte, XVI, pp.139-276; Pl.XV, figs.3-5; Pl.XVI, fig.16.


Camerina cf. kelatensis (Carter); Caudri, "Tertiary Deposits of Soemba", pp.53-56; Pl.1, figs.4-5,10.

Nummulites Beaumonti d'Arch. & Haime; Donciéux, "Contrib. à l'Étude géologique de la Côte Libano-Syrienne: Les Foraminifères éocènes de la Syrie septentrionale", p.211; Pl.XII, figs.1-2.

Nummulites Beaumonti d'Arch. & Haime; Flandrin, "Contribution à l'Étude paléontologique du Nummulitique algérien", Matériaux pour la Carte géologique de l'Algerie, (1), Paléontologie, No.8, pp.58-59; Pl.IV, figs.24-26.

The original Indian types of this species are now lost; but 9 specimens from Egypt still remain in d'Archiac and Haime's collections in the Muséum National d'Histoire Naturelle in Paris, to which I was kindly given access.
Professor C. Arambourg and Dr. J. Cottreau. I was able to identify, among these 9 specimens, the originals of d'Archiac and Haime's figures 1, 2 and 3 on their Plate VIII. I was allowed to photograph the original of figure 3 which is also shown as Fig. 1 of this paper, and I have the approval of Dr. Arambourg and Dr. Cottreau to cite it as the lectotype of the species.

The 9 original specimens vary from \(5\frac{1}{2}\) by \(2\frac{1}{2}\) mm. to \(10\frac{1}{2}\) by \(3\) mm. in size, the average dimensions being 8 by \(3\frac{1}{4}\) mm. The lectotype measures 9 by \(3\frac{1}{4}\) mm., and the stoutest form is the original of figure 3 which measures by \(4\frac{1}{4}\) mm. A form of average diameter (8 mm.) has 12 to 13 whorls. The specimens are about \(1\frac{1}{4}\) to \(1\frac{1}{2}\) times as high as long. There are about 54 chambers in the 10th whorl. Chamber partitions are almost straight, inclined at about \(10^\circ\) to the radius at bottom, and only slightly recurved at that point. There are 3 whorls in the outer half of a radius measuring \(2\frac{1}{4}\) mm. was allowed to prepare a meridian section of one of the less well preserved specimens, and this elicited the fact that the species possesses polar pustules, which extend between 0.8 and 0.9 mm. from the centre of the axis on either side. A remarkable feature, which becomes visible in the photograph of the lectotype is examined under a lens, is the presence of the surface trabecules on the filaments.

The Spin Tangi forms agree fairly well with this. They vary from \(5\frac{1}{2}\) by \(3\frac{1}{4}\) mm. to \(10\) by \(4\frac{1}{4}\) mm. in size, the average dimensions of a large number of specimens being \(7\frac{1}{2}\) by \(3\frac{1}{4}\) mm. The ratio of thickness to diameter seems constant at \(1:2.3\) for all sizes, although individual variations range from \(1:2.0\) to nearly \(1:3.0\). The spire is very regular, chambers and whorls increasing slowly and evenly in size. Specimens of average diameter \(7\frac{1}{2}\) mm. have 12 or 13 whorls, with about 60 chambers in the last one. There are 3 whorls in the outer half of a radius measuring \(2\frac{1}{4}\) mm. The marginal cord is thinner than in d'Archiac and Haime's types, in which the cord aped to equal about a quarter of the height of the subjacent chambers. Chambers are about twice as high as long in the inner whorls, but their height hardly exceeds their length in the outer whorls. Chamber partitions are almost straight, nearly vertical at bottom, and only slightly recurved at that point. The test is smoothly lenticular, with septal filaments almost straight at the periphery but curved round at the poles. Meridian sections are very characteristic, with buried polar pustules, which extend about half way from the centre to the surface, and are more or less abruptly succeeded by pustules of the outer polar pillars which themselves fade out before reaching the surface. Transverse trabecules are sometimes seen, but are rudimentary.

Distribution. I have only hitherto found this species in the uppermost Spin Tangi beds of Baluchistan, and in collections from one beds near Siju (25°28'; 90°04') in eastern Bengal, not far from Cherrajpur where some of d'Archiac and Haime's original Indian types of N. beau- tai were collected. Both Dalton and Cotter thought they found N. beaumonti in the uppermost Eocene beds near Kyet-u-bok (19°59'; 94°40') in Burma, and is probably to this species that they refer. The species certainly applies beyond Burma to the south-east, for it has been figured and described I. kelatensis etc. by Dutch palaeontologists and have found it in the Eocene beds of the Dutch East Indies. The buried pustules of the Dutch E.I. form are well seen in a meridian section of a specimen from Dr. C. M. B. Coudri, who is one of the few palaeontologists who realise the importance of systematically showing meridian sections as well as equatorial ones in dealing with Nummulitidae. Doornink, who thought it a new
species also shows the buried polar pustules (Pl.VIII, fig.3), and notes the presence of transverse trabecules on the filaments. The degree of development of these trabecules seems to vary a good deal.

In the opposite direction, the species seems to extend as far as the eastern Mediterranean, for it appears, though rarely, in Algeria. M. Flamar, who does not figure the meridian section, tells me that his Algerian forms have buried polar pustules, and agree with my descriptions of the M. type.

As to the vertical distribution, it states that the species appears in the Auversian, Bartonian and Luidan; Doncieux states that the Egyptian and Syrian N. beaumonti appear in the Upper Lutetian and Bartonian; andrén says that the Algerian specimens appear in the Auversian. It is clear, therefore, that the species is an upper Eocene one. Its appearance in the top of the Spin Tangi section would indicate that the "Spintangi" (upper Khirthar) beds of N.W. India are either late Lutetian or post-Lutetian in date, and may be provisionally referred to the Auversian.

Associates. The associates of N. beaumonti at Spin Tangi are Assillina rota n.sp. (described below), Dictyococonoides kohaticus var. tangiensis, Alveolina elliptica, Nummulites cf. complanatus, and some other forms which I have not yet worked out.

Illustrations.

Fig.1. N. beaumonti. LECTOTYPE. Original of d'Archiac and Haimé's Plate VIII, fig.1. From Egypt; exact locality and horizon unknown. External view, magnified 4 times.

Fig.2. N. beaumonti. Specimen from uppermost levels of Khirthar limestones at Spin Tangi. External view, magnified 4 times.

Figs.3 & 4. As fig.2, but different specimens.

Fig.5. As fig.2, but lateral section, showing grouping of buried polar pustule and pillars near centre of test. Magnified 8 times.

Fig.6. As fig.2, but equatorial section. Magnified 8 times.

Fig.7. As fig.2, but meridian section, showing buried polar pustules. Magnified 8 times.

Fig.8. N. beaumonti. Specimen from Upper Siju, Garo Hills, Assam. Meridian section, for comparison with fig.7. Magnified 8 times.
Nummulites pinfoLDI n.sp.
(Figures 9 to 14)


liated form:

1926. Nummulites beaumonti d'Arch. & Haime; Nuttall, "Zonal Distrib. of larger Foraminifera of Kirthar Series", Rec. Geol. Surv. Ind., LIX, pp. 130-131; Pl. I, figs. 4-5.

Very common in the Kohat Shale is a form which seems to be related to Spin Tangi Nummulites just described as N. beaumonti, although it is normally different, being smaller, and having a flattened or excavated pustule at each pole, instead of being externally devoid of granules or pustules in the adult state. In the northern parts of the Kohat-Potwar, both east and west of the Indus, this species is represented by small-specimens than further south. Thus specimens from the Shekhan nullah average 4.2 by 2.1 mm. in size, the largest measuring 6.0 by 2.5 mm.; but specimens collected at Bahadur Khel average 6.1 by 2.3 mm., in size, the largest measuring 8.1 by 3.1 mm. The general average of all the forms is about 2.1 mm., which is considerably less than the average size of the Spin species; but the ratio of thickness to diameter is much same as in that species. The number of whorls in this Kohat Shale form es from 10 to 12 at 6 mm. diameter, and there are about 55 chambers in last whorl at that size; which facts agree with the Spin Tangi N. beaum-
L. As with the latter, there are 3 whorls in the outer half of a radius dure 2.1 mm. The marginal cord is similarly thin; the height of the pustules equals about twice their length in the inner whorls, but only about a half times their length in the outer ones; and the septa are all-straight, often nearly vertical at bottom and little recurved at top. these features indicate affinity; and so this Kohat Shale form, despite very distinctive external appearance, may possibly be a premutation of later true N. beaumonti. I certainly do not, however, feel justified in tifying it with the latter; and as I know of no other form to which it be referred, I propose to treat it as a new species and call it N. pin-
I after my late colleague Mr. E. S. Pinfold of the Attock Oil Company.

Distribution. I have found N. pinfoLDI in all exposures of the Kohat Shale in the Kohat-Potwar basin (Attock and Kohat dist-
), and it also appears in Mr. Pinfold's collections from Waziristan. may be a northern variety of the form called "N. beaumonti" by Nuttall; the latter shows no external polar pustule, and Nuttall unfortunately no meridian section which might reveal a buried pustule. Nuttall's is considerably smaller than true N. beaumonti, and its distinction
from *N. beaumonti* and from *N. pinfooldi* is indicated by its distinctly crowded spire, there being four whorls instead of three in the outer of a radius measuring $2\frac{1}{2}$ mm. *N. pinfooldi* occupies a somewhat intermediate position between *N. globulus* Leymerie and *N. beaumonti*. For description the Indian representatives of *N. globulus* see my Thal paper (1927, pp. 271-273; Pl.XX, figs.6-10).

**Illustrations.**

Fig. 9. *N. pinfooldi*. HOLOTYPE. From the Kohat Shale in the Bhagwan Kas nullah. External view, magnified 4 times.

Figs. 10 & 11. Two other specimens from the same locality. External view, magnified 4 times.

Fig. 12. *N. pinfooldi*. From the Kohat Shale near Kohat. Equatorial section, magnified 8 times.

Fig. 13. *N. pinfooldi*. From the Kohat Shale of the Bhagwan Kas nullah. Meridian section of a small, stout specimen.

Fig. 14. *N. pinfooldi*. From the Kohat Shale at Bahadur Khel. Meridian section of a large specimen.

**Assilina papillata** Nuttall.

(Figures 15 to 18)

1879. *Nummulites exopenens* Sowerby; Fedden, "Table showing distribution of Sind fossils enumerated in Messrs. d'Archiac and Haime's Description des Animaux Fossiles de l'Inde," Mem. Geol. Surv. Ind., p. 199.

1879. *Nummulites granulosa* d'Archiac (pars); Fedden, loc. cit.

1879. *Nummulites spira* Roissy (pars); Fedden, loc. cit.

1915. **Assilina exopenens** (Sowerby) (pars); Dainelli, "L'Eocene Friuliano", p. 193; Pl.XXIV, figs.1,5,7, etc.

1926. **Assilina papillata** n.sp.; Nuttall, "Foraminifera of Middle and Lower Khirthar Series", Rec. Geol. Surv. Ind., LIX, pp. 144-145; Pl.VI, figs. 5-7.

This species, as found in Sind, has been well figured and described by Nuttall. It is very common in the Kohat and Attock districts, and in Wazstan. Its average diameter is about the same (17 mm.) in the north as in Sind, although specimens measuring 20 to 21 mm. are fairly common in the north, as against the maximum of 19 mm. reported in Sind, and the northern
is seem to be relatively thinner than those observed by Nuttall. These minor matters; but I would amend Nuttall's description in one respect, he says that the thickness of the test is practically the same at the tre as at the periphery. In actual fact, the centre is nearly always avated, as Nuttall's own external views indicate, and as meridian sec-

is clearly prove; for the whorls are evolute practically from the first. is due to this evolute character that the marginal cord often shows so luminently, causing the species to be referred to A.spira. At other times later whorl enfolds the marginal cord only of its predecessor, and the re is then indicated by a depression as shown in Nuttall's fig.7. Equat-

sections show considerable variation, the spire being characteristic-

loose and irregular, while the spacing of the chambers is equally instant.

Distribution. According to Nuttall, this species appears in the upper part of the Middle Khirthar in Sind. In the north, it is common throughout the Upper Chharat beds (Kohat and Nummulite Shales) the Kohat-Potwar basin and Waziristan. I have also found it in collec-

s from Eastern Bengal (though not associated with N.beaumonti). Wha-

ing the collections of the Geological Survey of India in Calcutta, ng my last visit to India (1936), I found this species repeatedly oc-

ing among the original types of Fedden and T.Rupert Jones. Apparent-

ly had variously referred members of it to "Nummulina granulosa" (Reg. H.43/175 and H.43/176), "N.spira" (Reg.No.H.43/179), etc., while Jones ed No.H.43/173 "N.complanata" though Fedden doubtfully referred the to "N.exponens". It would seem, from his illustrations, that Dainelli similarly referred members of this species to Assilina exponens, which mind is far less excusable than confusing them with A.spira.

Illustrations.

Fig.15. Assilina papillata. From the Kohat Shale near Kohat. Ex-

ternal view, showing a specimen with exception-

ally prominent marginal cord. Magnified 2 times.

Fig.16. Another specimen from same locality as Fig.15. Exter-

nal view of specimen with less prominent cord, with intermediate in type between Fig.15 and Nuttall Fl.6, fig.7. Magnified 2 times.

Fig.17. Assilina papillata. From the Kohat Shale near Kohat. Equa-

torial section, showing loose and irregular spire. Compare with Nuttall's Fl.6, fig.6. Magnified 4 times.

Fig.18. Assilina papillata. From the Kohat Shale near Kohat. Mer-

idian section, not illustrated in previ-

ous works. Shows relative thinness of the test at the poles. Magnified 4 times.
Assilina rota n. sp.
(Figures 19 to 24)

In the upper levels of the Khirthar limestones at Spin Tangi, first appearing below the level at which N. beaumonti abounds but continuing into beds which contain N. beaumonti, I found many Assilines which differ materially from A. papillata although they may be related to it. Their tests decidedly involute instead of being evolute, and as a consequence show marked polar thickening. Owing to the rapid increase in the width of their chambers, coupled with the less involute nature of the outer whorls, the test often shows a swollen rim as well as a central boss. This tends to give the form a wheel-like appearance, for which reason I propose to call the species A. rota. The involute nature of the test causes the surface ridges to be much less prominent than those of A. papillata, but they apparently follow the same arrangement as in that species. The equatorial section shows a more regular and more closely wound spire than that of A. papillata. There are about 12 whorls in a radius of 7 mm. The specimens examined average 13\(\frac{3}{4}\) by 2\(\frac{3}{4}\) mm. in size, the largest measuring 18.3 by 2.8 mm.

**Distribution.** I have only seen this form at Spin Tangi in Baluchistan, and in the Sirki Shales of the Kohat district. Together with Dictyconoides kohaticus var. spintangiensis and Alveolina elliptica, it seems to date the Sirki Shales as Upper Khirthar. The characters of the species are not so well marked, however, in the Sirki Shales specimens as in the Spin Tangi ones. The former, while sometimes characteristic, are on the whole less obviously distinct from A. papillata. This may indicate the derivation of A. rota from A. papillata; and, together with the occurrence of N. beaumonti, it suggests that the Sirki Shales are slightly older than the latest Spintangi levels.

**Illustrations.**

Fig. 19. **Assilina rota.** HOLOTYPE. From upper levels of Khirthar limestones at Spin Tangi. External view. Magnified two times.

Figs. 20 to 22. Three other specimens of same species from same locality as Fig. 19. External view, magnified two times.

Fig. 23. **Assilina rota.** From upper levels of Khirthar limestones at Spin Tangi. Equatorial section. Magnified 4 times.

Fig. 24. **Assilina rota.** From upper levels of Khirthar limestones at Spin Tangi. Meridian section. Note the involute nature of the early whorls, causing the central thickening; and the rapidly increasing width of the spire, tending to produce a marginal thickening. Magnified 4 times.
Assilina shekhanensis n. sp.

(Figures 25 to 27)

1924. Assilina granulosa (d'Archiac); Davies, Journ. Asiat. Soc. Bengal (N.S.), XX, p. 213.

1925. Assilina granulosa (d'Archiac) (pars); Nuttall, Quart. Journ. Geol. Soc. Lond., LXXXI, p. 443; Pl. XXVI, fig. 2.


When describing the Salt Range fauna, I provisionally referred this species to Dr. Doncieux's species A. pustulosa; but I have since been given specimens of A. pustulosa by Dr. Doncieux himself, and find that the Indian species is quite distinct from his one, which is both smaller and relatively touter, and has an altogether different meridian section. It seems necessary, therefore, to treat the Indian form as a new species, and I propose to call it A. shekhanensis after the Shekhan Limestone in which it most probably occurs. I have little to add to the description of the form given in my Range memoir (1937), except to say that I have since found that it is considerably in size, presumably according to local conditions, for average specimen in one exposure of a bed may be larger than any seen to date. Thus the average size varies from 6½ by 1½ mm., in some exposures to 10 by 1½ mm., in others; the general average is 6½ by 1½ mm., and the largest specimen observed was measuring 11.5 by 2½ mm. In all specimens the essential features are the same, and the easily "wasp-waisted" appearance of the meridian section proved that the size is evolve from the first.

Distribution. This species characterises the upper levels of the Laki formation, occurring in the Ghazij Shales of Baluchistan and the rare beds of the Salt Range. It is the principal Assilina found in the Laki Limestone, or latest Laki formation in the Kohat-Potwar basin. It does not seem to survive the Laki, although externally similar forms are to be seen in some exposures of the Kohat Shales. The latter are less excavated at the poles, however, and are actually megalospheric forms. Their micritic companion, which must be far larger, has not yet been found by me, they do not seem to survive into the Nummulite Shale. These Kohat Shales, which might be mistaken for A. shekhanensis, may possibly be derived from the latter, but are not identifiable with it.

Illustrations.

Fig. 25. Assilina shekhanensis. HOLOTYPE. From the Shekhan Limestone at Chikar Kot, near Kohat. External view. Magnified four times.

Fig. 26. Assilina shekhanensis. From the Shekhan Limestone in the Shekhan nullah, Kohat. Equatorial section. Magnified eight times.

Fig. 27. Assilina shekhanensis. From the Shekhan Limestone in the Shekhan nullah, Kohat. Meridian section. Magnified eight times.
Assilina subshekhanensis n.sp.

(Figures 28 to 32)

Accompanying A. shekhanensis, and obviously its megalospheric companion, a small form with excavated poles and prominent spines, which has a very distinctive appearance in thin sections of Shekhan Limestones. Its average size is about 3 by 1 mm., the largest observed measuring 3.7 by 1.2 mm. The protoconch is double and subequal, the diameter of each cell varying from 0.14 to 0.28 mm. in extreme cases, but averaging 0.2 mm. There are about 5 whorls in specimens measuring 3.5 mm., the numbers of chambers the whorls respectively averaging 7:15:21:26:33, although the observed variations in numbers are respectively 6-7:13-17:19-24:21-28:31-35. The original cord is thin, and the chamber partitions are almost straight and lined forward at about 30 to 40 degrees to the radius.

Distribution. This form appears together with A. shekhanensis in practically all exposures in which I found the latter. I have never seen it appearing where the latter was not also present.

Illustrations.

Fig. 28. Assilina subshekhanensis. HOLOTYPE. From the Shekhan Limestone at Chikar Kot, near Kohat. External view. Magnified four times.

Figs. 29 & 30. Same species, from same locality, as Fig. 28. External view. Magnified four times.

Fig. 31. Assilina subshekhanensis. From the Shekhan Limestone at Chor Galli. Equatorial section. Magnified sixteen times.

Fig. 32. Assilina subshekhanensis. From the Shekhan Limestone at Chor Galli. Meridian section. Magnified sixteen times.

Assilina tattaensis (d'Archiac & Haime).

(Figures 33 to 37)


Carter long ago described as an Operculine an Assiline which he found at Tatta in Sind. After being referred to Carter's description and figures, and called the form O. tattaensis, while remarking on its relatively closely-wound spire which affilit it to the Assilines. It has since been affilit with A. spirala by Nuttall, and A. granulosa by Nuttall. It is certain that Fedden was wrong, and Nuttall, in his mistake by first confusing A. papillata with A. spirala, and then \textit{A. granulosa}, at the same time, this species with A. papillata, has led to the term \textit{A. granulosa} has of late become so excessively holic that it has ceased to serve any exact stratigraphic purpose; so I am recently felt compelled to confine its application to the forms which exactly correspond with those to which it was originally applied, giving other designations to slightly different forms which actually characterize somewhat different horizons. Whether or not these differences represent limits of zoological species, nobody can say. The species of the palaeontologist are based on more limited information than those of the zoologist, and are directed to other ends - primarily stratigraphic, with a view of elucidating the contemporaneity of deposits, and hence the details of orogenic sequence. The palaeontologist cannot allow his ideas to be confused with physiological speculations. His objective criteria are purely morphological, and by them he must abide. Hence, owing to elimination of forms not exactly corresponding with the original types of \textit{A. granulosa}, the old species \textit{A. tattaensis} again emerges as a type deserving separate recognition; and as such it is here proposed to treat it.

The original material on which this species was founded being in Carter's collections, I referred to the latter, and have selected what seems to be the best-preserved remaining specimen, referred to this species by Carter himself, to serve as lectotype. It is shown below as fig. 33. Similar specimens were found by me in the Kohat district. The Kohat form is larger than Carter's, although overlap occurs, some specimens from Kohat seeming to be indistinguishable from Carter's specimens. The Kohat specimens average 14 by 1.6 mm. in size, the largest observed measuring 16.6 mm. There are about 10 whorls in a radius of 7 mm., with about 60 chambers in the outermost whorl. The height of the chambers equals from three to four times their length, the relative height being actually greater in the outer whorls than in the inner ones. The chamber partitions are formed for the most part vertical, straight, but boldly recurved in their upper quarter. There is often a small granular boss at the pole, and the ta and cord are also granulated; but the whorls are non-enveloping almost from the first, except that the cord itself is sometimes enfolded by the succeeding whorl - which tends to produce a depression along the course of a whorl.

\textbf{Distribution.} The species seems to characterise a fairly low Laki level in Sind. It is very abundant in an outcrop of Laki beds a mile 40 on the Kohat-Thal road. The position of this outcrop is uncertain; it may be older than the Shekhan Limestone, since I found no A. she-
in it. On the other hand, *A. tattaensis* does survive into the Limestone level, since I found a few representatives of it in the Limestone outcrops, abounding with *A. shekhanensis*, at Chikar near Kohat.

Illustrations.

**Fig. 33.** *Assilina tattaensis* (d'Archiac & Haime). Lectotype: Specimen No.P. 33143, in the Carter collections at the British Museum (Nat.Hist.) in London. External view. Magnified three times.

**Fig. 34.** *Assilina tattaensis*. Laki outcrop, near Mile 40, Kohat-Thal road. External view. Magnified three times.

**Fig. 35.** As Fig. 34; large specimen from same outcrop. External view. Magnified three times.

**Fig. 36.** *Assilina tattaensis*. Laki outcrop, near Mile 40, Kohat-Thal road. Equatorial section. Magnified four times.

**Fig. 37.** As Fig. 36, but Meridian section. Magnified four times.

**Discocyclina thalica** n.sp.

* (Figures 38 to 40)

In the Lower Ranikot sandstones and shales of Kurram Picquet hill at I found a number of very small lenticular microspheric and megalospheric Discocyclines which obviously constitute a pair. The microspheric which I propose to call *D. thalica*, measures about 3 by 1 mm.; the rest observed measures 3.25 by 1.1 mm. It is covered with pillars, increase in thickness while passing from the equatorial layer to the dor, where they measure from 0.06 to 0.12 mm. in diameter; the thickening near the poles. The equatorial layer of chambers is about 0.04 mm thick, and the chambers measure about 0.03 by 0.035 mm. at 1 mm. from centre; the cyclical rings are about 0.035 mm. in height at that dist-Rosettes surrounding pillars are formed by 6 to 8 radiating verticals; lateral sections show networks of lines resembling a honeycomb, of the irregular polygonal cells are about 0.3 to 0.6 mm. in diameter. It is difficult to deal with the species, owing to its small size. I wish to record it, however, since it is the earliest true Discocycline to appear in the Ranikot beds. The large and well developed *D. ranikotensis* first appears slightly higher level.

Illustrations. I have only seen this form in the Lower Ranikot beds at Thal.

**Fig. 38.** *Discocyclina thalica*. Holotype. Specimen from Lower Ran-
**Discocyclina subthalica** n. sp.  

(Figures 41 to 43)

This is the megalospheric companion of *D. thalica*, and not much smaller, averaging about 2 by \( \frac{3}{4} \) mm. in size. The largest observed measures by 0.8 mm. Its external characters are similar to those of *D. thalica*. The test is lenticular, and the pillars are from 0.06 to 0.08 mm. thick. The equatorial layer of chambers is about 0.035 mm. thick near the protoch, and 0.055 mm. thick near the periphery. The protoconch is double; the smaller cell, measuring about 0.10 to 0.12 mm., is almost completely rounded by the larger, measuring about 0.20 to 0.24 mm. The equatorial ribs are from 0.03 to 0.05 mm. in height, and the chambers into which they subdivided are practically square, the tangential measurement being less than the radial. Rosettes etc. are as described for *D. thalica*.

**Distribution.** I found this form together with *D. thalica* in the Lower Ranikot beds at Thal, and also identified it in sections of the Upper Ranikot limestones outcropping 20 miles east of Thal.

**Illustrations.**

**Fig. 41.** Discocyclina subthalica. HOLOTYPE. Specimen from Lower Ranikot beds of Kurram Picquet hill. External view. Magnified eight times.

**Fig. 42.** Discocyclina subthalica. From same locality as Fig. 41. Equatorial section. Magnified twentyfour times.

**Fig. 43.** Discocyclina subthalica. From same locality as Fig. 41. Meridian section. Magnified twentyfour times.
Alveolina ellipsoidalis Schwager.
(Figures 44 to 46)

1883. Alveolina ellipsoidalis n.sp. (pars); Schwager, Palaeontographica, XXX, pp.96-98; Pl.XXV, figs.2, a-c.

1933. Alveolina elliptica (Sowerby); Silvestri, Palaeontographia Italiana, XXXII, Suppl.3, Pt.IV, pp.53-54; Pl.III, fig.2; Pl.XII, figs.1-8.

In the Upper Ranikot beds at Thal, and in Mr. Pinfold's collections from the Upper Ranikot beds of Waziristan, appears a small ovoid Alveolina which is relatively stouter than Alveolina vredenburgi, which it sometimes accompanies; internal sections show that its whorls are less crowded than those of the other species, and its chamberlets much larger. Its whole internal aspect is much coarser. The average size is about 2 1/2 by 1 1/2 mm., the largest measuring 3.0 by 1.33 mm. The protoconch averages 0.12 mm. in diameter, varying from 0.10 to 0.14 mm. There are 9 to 10 whorls in specimens of 1 1/2 diameter; about 5 major chambers; and 12 to 16 chamberlets per 1 mm. in the outer whorls. There is no trace of flossculinisation, but the structure of the test is thick throughout. So far as I have seen, the already described form which matches it most closely is one of Schwager's illustrations of Alveolina vredenburgi, which shows a specimen 2 1/4 by 1 3/4 mm. in diameter, with protoconch measuring 0.07 mm. in diameter, about 10 whorls, six major chambers, and 13 cells per 1 mm. in the outer whorl. The same may either be a megalospheric companion, of the much larger form, or the megalospheric companion, of the much larger form, with smaller protoconch also figured by him. In the meantime, I provisionally refer this Ranikot species to Schwager's Alveolina vredenburgi.

Distribution. As noted above, this species has only been seen hitherto in the Upper Ranikot beds of the Kohat district and Waziristan, in the Indian region. If rightly identified with Alveolina vredenburgi, it appears at a rather higher level (Lybian, or Lower Eocene beds, approximately corresponding with the Indian Laki formation) of the Egyptian region. Silvestri's runs recently figured a very similar form, measuring about 2.5 by 1.9 mm., which appears in what is supposed to be an erratic block of Eocene age in Somaliland. Its protoconch varies from 0.13 to 0.23 mm. in diameter, and it has about 9 whorls and from 12 to 16 chamberlets per 1 mm. in the outer whorls. I cannot understand how this collector could have described this diminutive species to Sowerby's much larger, later, and totally different Alveolina elliptica. There is no sort of resemblance between the two species. On the other hand, the most striking difference between Silvestri's and my Ranikot one lies in the fact that his is less elongate, and is less thickening of the spiral layers towards the poles; but both of these differences may be due to the imperfect orientation of his sections. My case, the affinity between the possibly Mesozoic Somaliland form and undoubtedly Palaeocene (Upper Ranikot) Indian one indicates the antiquity of the type. The nearest known Indian equivalent of the latter is the early Laki species which was referred to Alveolina by Nuttall in 1925, but myself in 1938 (Nature, 29/1/1938, p.202). But Alveolina is a micritic form, and has smaller chamberlets than the Upper Ranikot species.

Illustrations.

Figs.44 to 46. Alveolina ellipsoidalis. From Upper Ranikot beds.
Alveolina vredenburgi Davies.

(Figures 49 and 50)


1926. *Alveolina oblonga* d'Orbigny (pars); Doncieux, *Ann. Univ. Lyon*, N.S., 1, fasc. 45, p. 76; Pl. VIII, fig. 2.


I recently described this form as a new species, in order to distinguish from *A. oblonga* to which it had previously been referred, but from which I became convinced that it should be separated. Further work on it has confirmed this opinion, but has brought out facts which necessitate a revision of the species. Owing to the fragile nature of the test, it has been very difficult to obtain good internal sections of it; but continued work has shown that it is very variable, and that later Ranikot specimens (among which the holotype was chosen) usually differ from earlier Ranikot ones in possessing a more crowded spire, with more numerous whorls, and more chambers per 1 mm. in the outermost whorl, at similar diameters. A meridian section of a Lower Ranikot specimen from Thal was shown in fig. 5 on p. 282 of my 1927 paper (cited above). I also showed, in the same paper, that the spire was more crowded, with more numerous chamberlets, in the uppermost Ranikot beds at Thal itself. In the Range Ranikot beds, some of which are younger than the Thal ones, these tendencies become still more marked. A meridian section of a late Ranikot
Specimen, of similar horizon to the holotype, is now shown below (Fig. 50). I could now redescribe the species as follows:

The ratio of diameter to axial length varies from over $\frac{1}{2}$ to less than $\frac{3}{4}$. The longest specimen seen measured 6.5 by 1.5 mm.; but the usual length under 4 mm.; average measurements of observed specimens being about $3\frac{1}{2}$ by $1\frac{1}{2}$ mm. The shape varies from cylindrical with rounded ends to very elongate with pointed ends, most specimens being distinctly fusiform. Late Ranikot specimens are usually larger than earlier Ranikot ones, and have more whorls, and more crowded chamberlets, at similar diameters.

Upper Ranikot. The number of whorls is about 20 for a diameter of 1.5 mm., with about 17 to 27 chamberlets per 1 mm. in the outermost whorls, but 25 to 35 per 1 mm. at 0.5 mm. radius, and from 30 to 40 per 1 mm. in earliest whorls. The later whorls exhibit from 6 to 8 major chambers. The protoconch is double, the larger cell varying from 100 to 150 $\mu$ in diameter, and the smaller cell having a diameter of about 40 $\mu$.

Lower Ranikot. The average size is about $2\frac{1}{2}$ by $1\frac{1}{2}$ mm., the largest observed measuring 3.5 by 1.8 mm. The number of whorls is about 8 for a diameter of 1 mm., with 13 to 15 chamberlets per 1 mm. in the outermost whorls.

Distribution. The Lower Ranikot forms were found by me in the outcrop of Kurram Picquet hill, where they accompany D. subthalica, D. wadiai, etc. The Upper Ranikot forms appear in the upper levels of the Khairabad Limestone, or equivalent horizons elsewhere, north-west India, and are found in various outcrops at all levels of the Sitala Shales (i.e. to the end of Ranikot times).

**Illustrations.**

Fig. 49. *Alveolina vredenburgi*. HOLOTYPE (G.S.I. Type No. 15695). From the Patala Shales at Makarwal, western Salt Range. External view. Magnified eight times.

Fig. 50. *Alveolina vredenburgi*. From the Patala Shales near Kala-bagh, western Salt Range. Meridian section. Magnified eight times.
Alveolina violae Checchia-Rispoli.
(Figures 51 to 53)

1878. Alveolina oblonga d'Orbigny; Marinoni, Atti della Soc. Ital. di

1882. Alveolina oblonga d'Orbigny; Taramelli, Atti della R. Accad. dei

1905. Alveolina Violae n. sp.; Checchia-Rispoli, Palaeont. Italica, XI,
pp. 165-167; Pl. II, figs. 5-10.

1909. Alveolina granum festucae Bosco., var. elongata d'Orbigny (pars);
Osimo, Palaeont. Italica, XV, pp. 87-88; Pl. V, figs. 32, 34.

1915. Alveolina Violae Checchia-Rispoli; Dainelli, "L'Eocene Friulano",
pp. 166-167; Pl. XVI, fig. 8; Pl. XVII, fig. 5; Pl. XVIII, figs. 1-5.

There appears, in the Middle Khirthar beds of the Kohat-Potwar basin, an
rgated Alveolina whose presence has not hitherto been noted in India. It
ch much too long to be identified with A. oblonga, and much too slender in
portion to its length to be identified either with A. javana or A. elliptica.
Its nearest equivalents are A. violae, and the two forms (A. elongata
rbigny and A. frumentiformis Schwager) which are hardly distinguishable
A. violae. Those two, however, are more fusiform than the Indian spe-
whose usually blunted ends agree best with the similarly blunted ends
viola. It was, indeed, its rod-like shape which caused A. violae to be
named by earlier writers to A. oblonga, until Checchia-Rispoli rightly
ated it on account of its much greater relative and absolute length.

The Indian form averages about 11-1/4 by 2-1/4 mm. in size, although specimens
been seen measuring up to 16 by 3 mm., which is the normal size men-
ed by Dainelli for this species in Europe. The protoconch is double,
smaller cell measuring 0.10 to 0.15 mm., and the larger (which encloses
20 to 0.40 mm. in diameter. It has from 11 to 14 (usually about 12)
2 mm. diameter, and about 9 major chambers at the same. The num-
of chamberlets is about 14 to 15 per 1 mm. at 2 mm. diameter. There is
le or no flosculinisation in the middle of the test, but considerable
ening towards the poles gives it its rather cylindrical appearance.

The species is thus rather smaller than A. violae as figured and descri-
rom the Middle Eocene of Friuli; the latter apparently averaging about
y 3 mm. in size, and having 14 to 15 major chambers, 14 to 20 whorls,
3 to 15 chamberlets per 1 mm. in the outer whorls. But the differences
fly consist in the presence of more whorls and major chambers, and may
ue to the correspondingly greater size of the type form, whose proto-
sh is also rather larger, the big cell measuring 0.35 to 0.55 mm. I do
think it justifiable to separate the Indian form on this account, and
visionally refer it to the same species.

Distribution. Very common in the Kohat Shale, but also locally abundant
in the Nummulite Shale and Kohat Limestones of the Kohat-
ar basin. I have not yet seen it in any but Middle Khirthar beds.
Illustrations.

Figs. 51 & 52. *Alveolina violae*. From the Kohat Shales, Thal. Meridian sections. Magnified eight times.

Fig. 53. *Alveolina violae*. From the Kohat Shales, Thal. Equatorial section. Magnified eight times.
Illustrations.
Figs. 51 & 52. Alveolina violae. From the Kohat Shales, Thal. Meridian sections. Magnified eight times.

Fig. 53. Alveolina violae. From the Kohat Shales, Thal. Equatorial section. Magnified eight times.


I attach herewith six Text-figures (prepared separately from the text), plates showing the palaeontological figures (1 to 24 and 25 to 53 respectively) quoted above, the Legend for my map, and a sheet showing two sections of north-western Kohat district beds for comparison with the two areas given by Wynne which are reproduced alongside.

Wynne quotes no scale for his sections, and their vertical proportions obviously much exaggerated. These two old sections of his still represent the only ones hitherto prepared, apart from my own, of the portions of Kohat district mapped by myself (for the area concerned, see Text-fig. 1). My previous sections of beds within this newly mapped area were published in my Kohat (1924) and Thal (1927) papers, and the Samana memoir (1930).

The two sections now shown represent the same ground (as nearly as it could be identified) as is represented by Wynne's figures. Wynne had no ge-scale topographical map to work on, and his first section, extending from the Kohat Towi river to the highest peak to south of it a few miles south of Kangti, probably does not represent such a straight line as my corresponding section does. This may explain certain discrepancies in the contours. At the same time, the general line taken by his section cannot be different from that taken by mine; so it is certain that Wynne's beds, he regarded as successive, were really repetitions of the same very old series. Thus his beds numbered 2, 6, 10 and 12 were undoubtedly defensive outcrops of the Kohat Limestones, with Chharat beds at their base, while his number 7 is undoubtedly (vide his text, p. 107) the broad top of Lower Chharat conglomerate which appears about midway between river and the peak. It will be seen from my section that this outcrop actually dips to the north, instead of to the south as shown by Wynne. Perhaps the ground to south of it was obscured by detritus where he crossed, he may have mistaken joint planes for dip slopes. My own continuous survey made any such mistake impossible. The hasty nature of his survey made it impossible for him to check his first impressions, which were all that he could record.

As regards the Darsamand section (Wynne's and my second figure) I found clear evidence of a fault where Wynne shows one on the southern flank of mountain. What he saw was probably the outcrop of the Belemnite bed in places vertical) with sandstones to south of it obscured by detritus. The underlying limestones are, however, conformable, as continuous map showing. Wynne probably never went over the northern slopes of the
tain, about which he was obviously doubtful (I myself could only visit with an armed escort, and did so against the protests of the local tical Officer). So Wynne did not realise that Eocene beds appear there ly as they do on the southern flank.

II. By "Sabathu" beds, on his Fig. 1, Wynne meant (in the terminology of his day) representatives of the later parts of the Indian Nummul- sequence. The term, although still employed (like the equally vague sion "Hill limestone") by those who cannot trust themselves to define in terms of standard modern stratigraphy, has no exact stratigraphic e. Its use by Wynne was excusable and inevitable; but its continued today is simply an evidence of incapacity. It is noticeable that Wynne not apply the term "Sabathu" to the Eocene beds on the southern flank he Darsamand mountain. Those beds are actually as old as the oldest e known in Sind. Wynne could not have proved that fact, which has been established by my own recent work on Ranikot foraminiferal faunas; he had the palaeontological instinct to sense what he could not prove.

age 110 of his paper Wynne remarks on the "older aspect" of Eocene forms al, where I first established the presence of Ranikot beds. Those e were quite unknown in Wynne's day, but he had the genius to recognise both as Eocene and as early Eocene, although he had never seen them.

Acknowledgments.

As already indicated, I am indebted to the Attock Oil Company for facil- s in examining their sections east of the Indus, for comparison with ions in the Kohat district, and so obtaining a better conception of the Potwar basin as a whole. This is important, since that basin formed definite a unit during Eocene times. I am indebted to the Carnegie Trust the Universities of Scotland for a grant in aid towards the expense of t to India, and to the Director of the Geological Survey of Ind- or access to the Survey collections in Calcutta. I am much indebted to .Craig of the Department of Geology, of the University of Edinburgh, assistance in photographing the sections of foraminifera shown in con- ion with the palaeontological part of this paper.

Bibliography.

This paper is largely based upon my previously published works, which up to it, and which it serves to coordinate and complete. "This applies particular to my Salt Range memoir, published last year (1937). That ir, together with this paper, represents the post-graduation portion of tudes; and it adds considerably to pre-existing knowledge of Ranikot laki species, thus helping to fill the gaps in our knowledge of Indian he faunas where those gaps had been most pronounced. It was largel y to this improved knowledge of the earlier Eocene forms that I was to distinguish any local Eocene stage practically at sight, when I ened to the field in 1935-1936, and completed the mapping of Eocene s over an area more than 1,000 square miles in extent, before my give cut.

Under the circumstances, since the Salt Range memoir also represents
t-graduate work to the same end as this paper, and the bibliographies
both papers have so much in common, I have decided not to repeat the
each bibliography quoted in that memoir, but to quote only those additional
works (themselves only a selection) which have principally to do with this
er. The following, therefore, only indicates those works in addition to
ones quoted in the Salt Range memoir (pages 75 to 79) which are referre
directly or indirectly in this paper. Both bibliographies should be tak
as applying to this paper.

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TEXT-FIGURES 1-6.
The attached map, at 1" = 1 mile, combines the area mapped by myself (west of Gumbat) with the area mapped by the A.O.C. (east of Gumbat) in order to give a complete supplement to Wyne’s map of the southern half of the Kohat District.
TEXT-Figure 2.

**Distribution of the Upper Ranikot Sea.**

TEXT-Figure 3.

**Distribution of the Lower Lake Sea.**

Note: Initial emergence of north-west Himalayan axis. Further emergence of northern Afghanistan.

- **B** = Bunnu
- **D** = Delhi
- **G** = Gardez
- **H** = Haiderabad (Sind)
- **K** = Kohat
- **M.L.** = Manasarowar Lakes
- **Q** = Quetta
- **R** = Rawalpindi
- **S** = Srinagar
- **N** = Naini Tal
- **P** = Peshawar
- **Sv** = Subathu
- **T** = Thal
TEXT-Figure 4.

**DISTRIBUTION OF THE UPPER LAKI SEA.**

**NOTE:** SEVERANCE OF THE TRANS-HIMALAYAN ESTUARY. PONDING OF TRANS-HIMALAYAN DRAINAGE AND GENESIS OF UPPER INDUS AND JHELUM RIVERS, ETC. INITIAL EMERGENCE OF SALT RANGE AXIS. CONSEQUENT DESICCATION OF ISKHAL-PUTTAR BASIN.

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TEXT-Figure 5.

**DISTRIBUTION OF THE MIDDLE KHIRTHAR SEA.**

**NOTE:** ESTABLISHMENT OF UPPER INDUS RIVER. WESTWARD MOVEMENT OF NORTHERN MARINE WATERS. TEMPORARY MARINE INVASION OF RAJPUTANA. APPROXIMATION TO PRESENT KATHIAWAR COAST-LINE.
Correlation Table of Kohat District Zones, Pakistan, Baluchistan, and N.W.F.P.

- Lower Ranikot
  - Upper Ranikot
    - Lakh
      - Lakh, Lakh, Lakh
    - Lakh, Lakh, Lakh
  - Lower Ranikot
    - Upper Ranikot
      - Khairabad
        - Khairabad
          - Khairabad
  - Lower Ranikot
    - Upper Ranikot
      - Lakh
        - Lakh, Lakh, Lakh
  - Lower Ranikot
    - Upper Ranikot
      - Lakh
        - Lakh, Lakh, Lakh
  - Lower Ranikot
    - Upper Ranikot
      - Lakh
        - Lakh, Lakh, Lakh

- Lower Khirthar
  - Upper Khirthar
    - Lakh
      - Lakh, Lakh, Lakh
    - Lakh, Lakh, Lakh
  - Lower Khirthar
    - Upper Khirthar
      - Lakh
        - Lakh, Lakh, Lakh
  - Lower Khirthar
    - Upper Khirthar
      - Lakh
        - Lakh, Lakh, Lakh
  - Lower Khirthar
    - Upper Khirthar
      - Lakh
        - Lakh, Lakh, Lakh

- Lower Khirthar
  - Upper Khirthar
    - Lakh
      - Lakh, Lakh, Lakh
    - Lakh, Lakh, Lakh
  - Lower Khirthar
    - Upper Khirthar
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    - Upper Khirthar
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        - Lakh, Lakh, Lakh
  - Lower Khirthar
    - Upper Khirthar
      - Lakh
        - Lakh, Lakh, Lakh
Legend to Map of Kohat District.

- Upper Tertiary Sandstones and Shales.
- Sirki Shales, Kohat Lsts. and Nummulite Shale.
- Kohat Shale.
- Lower Chharat.
- Gypsum.
- Salt.
- Upper Laki.
- Lower Laki.
- Probably Ranikot.
- Upper Ranikot.
- Lower Ranikot.
- Mesozoic.
Figures 1-8: **Nummulites beaumonti** d'Arch. & Haime. (Text, pp. 38-41.)

Figures 9-14: **Nummulites pinfoldi** n.sp. (Text, pp. 42-43.)

Figures 15-18: **Assilina papillata** Nuttall. (Text, pp. 43-44.)

Figures 19-24: **Assilina rota** n.sp. (Text, p. 45.)
ILLUSTRATIONS.
FIGS. 1 TO 24.

NUMMULITES AND ASSILINES.
Figures 25-27: *Assilina shekhanensis* n.sp. (Text, p. 46.)

Figures 28-32: *Assilina subshekhanensis* n.sp. (Text, p. 47.)

Figures 33-37: *Assilina tattaensis* (d'Arch. & Haime). (Text, pp. 47-49.)

Figures 38-40: *Discocyclina thalica* n.sp. (Text, pp. 49-50.)

Figures 41-43: *Discocyclina subthalica* n.sp. (Text, p. 50.)

Figures 44-48: *Alveolina ellipsoidalis* Schwager. (Text, pp. 51-52.)

Figures 49-50: *Alveolina vredenburgi* Davies. (Text, pp. 52-53.)

Figures 51-53: *Alveolina violae* Checchia-Rispoli. (Text, pp. 54-55.)
Assilines, Discocyclines and Alveolines.
**Section No. 1:** About 8 miles E.N.E. of Hangy, corresponding with Wynne's Fig. 1 (reproduced below).

Scale 2" = 1 mile. Vertical and horizontal scales alike.

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**Section No. 2:** Through Darsamand Mountain, corresponding with Wynne's Fig. 2 (reproduced as left).

Scale 2" = 1 mile. Vertical and horizontal scales alike.