of trade at Rangoon. It almost all comes from Upper Burma and from the neighbourhood of Yenanchaung on the east side of the Irawadi about 60 miles above Thayetmyo. The greater part of the produce probably goes to Rangoon. In 1883-84 this part amounted to nearly 1,000,000 gallons, mostly taken by the Rangoon refinery, which produced 640,000 gallons of refined oil during the year. The oil is extracted in very primitive fashion, by wells ranging from 100 to 300 feet in depth according to position. Some wells yield as much as 200 gallons daily. Dr. Oldham when with the mission to Ava in 1855 observed that the measures consist of soft sandstones and shales of middle or lower tertiary age, considerably disturbed.[1] They are apparently less so than the oil-measures of Arakan. Oils of lighter quality are said to occur to the west of the river opposite Pagan and in the Chindwin valley. A notice of the small oil workings in Lower Burma was published in the Records of the Survey for 1870 (Vol. III, p. 72), and again in 1873, in Mr. Theobald's report on the geology of Pegu.[2] It is unquestionable that the oil resources of Burma admit of an indefinite extension of enterprise; yet the country still imports yearly about 2,000,000 gallons of kerosine oil from America. It is I think a safe prophecy that the oil-measures of Eastern India may be supplying half the world with light within a measurable time when the American oil-pools have run dry.

Report on the Petroleum Exploration at Khâtan, *by* R.A. TOWNSEND, *Superintendent of Petroleum Explorations in Baluchistan* (Plate I, fig. 4).[3]

Roads.

The Road from Sibi to Khâtan *viâ* Bioraji Hill passes nearly the whole distance over the fluviatile deposit which characterizes the plains of the Indus and no change is observable until the low sand hills are reached at Gazi, 24 miles east-by-south from Sibi.

These low hills continue with a gradual rise until the south side of Bioraji is reached; their composition is a coarse semi-compact sand, unfossiliferous, except an occasional vegetable marking, with a few ferruginous concretions. They contain thin plates of fibrous gypsum, which increase in number and thickness as Bioraj is approached, and all have a low dip, chiefly westward.

Eocene rocks.

At Bioraji a sudden change to eocene nummulitic rocks is noticeable, and there are not visible any signs of a gradual passage through miocene and pliocene, to fluviatile rocks, although no doubt the space between Gazi and Bioraji is occupied by miocene and pliocene formations. The strata on the south side of Bioraji are very much broken and faulted and dip at all angles between the horizontal and vertical; indeed some are thrown beyond the vertical, and their original lower has become their present upper surface.

[1] Appendix A of Colonel Yule's "Narrative of the Mission to the Court of Ava in 1855": reprinted, with other papers relating to the geology and minerals of Burma, by order of the Chief Commissioner in 1882.

[2] Mem. Geol. Surv. Ind. Vol X, Pt. 2.

[3] See para. 29 of the preceding paper.

Approaching Khátan by way of Thali and the Chakar river valley the same conditions prevail until a halting-place, Chakar Tung, is reached, and here begin a series of low ferruginous coarse-grained sand hills with strong red colouring; these are also unfossiliferous except slight traces of vegetable markings and concretions; they are, I think, upper miocene. At Turkhand, a little beyond this, towards Khátan, eocene rocks are again abruptly encountered, coming in with long straight ranges from the north-west bordering the valley leading to Mandi, and here a disturbance has taken place, producing probably a rift, which joins 3 miles further on with a deep synclinal which continues to and beyond the intersecting Sart valley, the latter passing through Khátan. At and near Turkhand the disturbance has been great and the contortions and foldings of the strata are surprising. The synclinal and rift form the water-course of the Chukar river. The fossils found thus far, differ in no way from those found at Khátan and need not here be considered.

Synclinal.

Entering the Sart valley the outer range on the right begins with a low out-cropping of nummulitic limestone dipping to the north at an angle of 60°. Bands of earthy shale containing Cardita are inter-stratified with the limestones, and the latter are composed chiefly of sub-angular fragments varying in size from an inch to two feet in diameter; several of these strata show a thickness of from 3′ to 20′; a few hundred yards behind these is the range proper, the top of which is composed of nummulitic limestone, rising from the synclinal in broken curves, it continues on to the south-west, gradually increasing in height until the highest point is reached at the Maurani peak, 4,800′ above sea-level. The axis of the range traced thus far, a distance of about 5 miles, is that of a gentle curve to the south-west with the concave side facing the Khátan river, the dip decreasing uniformly from 60° to 25°, and from north to nearly west at Maurani. A little to the south of the peak what appears to be a distinct and separate range intersects the Maurani ridge very obliquely; but on examination it is found to be a continuation of the original range produced by a faulting of the latter; it continues to bend to the south and east in irregular heights to beyond the Bioraji pass, and finally sinks down to the synclinal already named. It will thus be seen that the axis of the whole range describes an elliptical, or a rather horseshoe form, enclosing the Khátan valley.

Sart valley.

Axis of range.

From the fault on to Bioraji, the rocks are thrown into a great variety of positions, vertical, and at every conceivable angle. Beyond Bioraji the dip again becomes fairly regular and is always at right angles to the axis, outward.

On the lower reaches of the river, the rocks are composed of angular clunchy limestone in alternating layers, each about 15′ thick, and between which are beds of earthy shales varying from 3′ to 12′ in thickness; all these strata are standing at a dip of 60° towards the north, but to the south-westward they gradually fall to about 25°; none of them reach the crest of the ridge, having been removed by denudation.

Lying conformably on the outer stratum of these clunchy limestones (see section, plate I, fig. 4) is a seam of brown coal or lignite about 20″ thick, above and below which are a few inches

Lignite.

of what appears to be volcanic ash of sub-aerial deposit, within this seam are occasional concretions of ironstone, very hard and containing iron pyrites, and Turritella, &c. The coal or lignite is of no value as a fuel, as it contains so large a percentage of sulphur and its compounds as to make it unsuited for contact with iron furnaces or boilers. The deposit is small and erratic, appearing occasionally further south-west in the outer range in thin ashy plates with dark carbonised markings.

Marine conglomerate.

A little further up the river bed on the left appears for the first time what I have considered to be a conglomerate of marine origin on the surface of which are patches, the remains of a fine-grained dark blue shale-like limestone, which where exposed becomes prominent because of its double jointed structure producing angular blocks, the whole resembling a ruined fortification. This and the conglomerate are the only rocks exposed over the surface of the inner mountain, all original superincumbent rocks having disappeared by weathering and denudation.

Inner cone.

The longest diameter of the inner mountain corresponds to a line passing through its centre nearly east and west, and such a line also divides the mountain into two equal parts, one with its strata dipping pretty constantly to the north, and those of the other to the south—in fact, it is a gently folded cone, around the base of which the river takes its course from the eastward, the valley embracing the space between this and the inner base of the outer range.

Crater appearance.

From an elevated position the whole presents the appearance of a volcanic crater with a cone in its centre, but only in appearance, as not a trace of true volcanic origin is discoverable.

Transverse section.

A transverse section of the range, valley, and a portion of the cone is shown in fig. 4. This section is made to bisect the maidan (plain or terrace) on which are located two borings for petroleum, and is fairly representative of the character of the whole range.

Beginning at the top of the range shown in section, we find a prominent and heavy stratum of nummulitic limestone, about 300′ thick at this point, marked Nos. 1, 2, 3, 4. No. 1 is massive of slightly yellow colour and is rather porous although very firm; it is uncrystallized and abounds in nummulites, nautili and other molluscs and radiates. Strata 2, 3 and 4, also nummulitic, differ from No. 1 only in colour and texture, 2 being massive, of a pale yellow colour, and hard and clunchy in structure. No. 3 is identical with No. 1. No. 4 is very white, rather soft and chalky; all contain nummulites and break with a fracture vertical to their line of bedding in planes, not unlike basalt. Nos. 5, 7, 9, 11, 13 and 15 are all strong beds of light brown earthy limestone, and between them are numerous bands of thin limestone from 1 inch to 1 foot thick, with thin clay and shale bands; all these are covered with debris and can only be examined in one or two places, but judging from their broken fragments they are all sub-divisions of the nummulitic series. No. 6 is a curious combination of angular blocks of white limestone. No. 8 is a heavy seam of very pure white gypsum in many places 15′ in thickness, extending throughout the whole length of the range. In many places very beautiful markings of pink colour are found, caused no doubt by iron oxide in a state of solution. No. 10 is another heavy band of grey gypsum, in all respects like No. 8, except in colour and co-extensive with it. No. 12 is also gypsum, but is a thinner deposit, being only about 3′ in thickness and less pure than the others; all are unfossiliferous and are beautifully exposed in many places. No. 8, being massive, it is quite possible that blocks sufficiently large for artistic purposes could be obtained from it. Between Nos. 15 and 16 there is a trace of lignite with volcanic ash which appears in an erratic manner on the top of No. 16. Immediately above the lignite is a deposit of very friable coarse shale, weathering into mud if wet, teeming with echinoderms and small Cardita. Nos. 16, 18, 20, 22, 24 are all continuations of the clunchy limestones mentioned as appearing on the lower reaches of the river; and Nos. 17, 19, 21, 23 correspond to the earthy shales between them, but here they have lost their earthy character and are very beautifully coloured soft shales, with, in places, enormous quantities of fragile carbonized nummulites which crumble at a touch. No. 25 is a thick deposit of silky olive shales with numerous concretions of vegetable origin; the majority of them are soft and contain often pieces of carbonized wood in good preservation. No. 26 is a band of dark brown flint which here appears for the first time; it is not uniform in deposition, many breaks occurring, but it can be traced for miles always in the same relative position, that is, between Nos. 25 and 27. The latter is also a soft olive shale differing only from 25 in having singular and large masses which have become indurated, and which have a slaty cleavage and are highly carbonaceous. It is in these two deposits of shale that the first traces of petroleum are discovered and in several places where vertical faces are exposed to the direct sun's rays, bituminous drops and threads mark them with a jet blackness. Beyond the concretions named I have not discovered any fossils in these shales. No. 28 is another band of flint of very dark colour of about 1 foot thickness, and is I think throughout composed of sponge spicules; in many places the original sponge form is retained, but so cracked are they that it is difficult to remove one in a perfect condition.

Wherever this band appears among the low shale hills on the terraces at Siah Kuch or elsewhere in the valley splendid specimens of fossil sponges abound, all rather large for transport. Besides flints thin plates of fibrous gypsum from ¼″ to 1½″ in thickness occur; they are very hard and of dark brown colour, and are scattered through the shales last mentioned and appear to have been formed from waters holding in solution sulphate of lime in their passage through openings caused, no doubt, by slipping; these plates give a metallic sound when struck together. Nos. 29—31 are similar to 27, and No. 30 is a repetition of 28.

Rocks conformable.

Thus far all the rocks exposed are lying conformably upon each other, and all may be said to contain nummulitic fossils, except the last shales (No. 31) and the flints; a total thickness of about 4,600′ is exposed, vertical to the line of bedding.

Inner hill.

Having crossed the river bed we enter on rocks quite different from any so far described. No. 32 is a fine-grained hard blue limestone in divisional planes of various thickness from 3″ or 4″ to 2′, and jointed in structure by straight parallel planes of fracture vertical to plane of bedding and crossing each other at various angles. Some of the blocks thus produced are singularly uniform in their dimensions and wonderfully straight and smooth on their surfaces; as before stated, these resemble a masonry wall. Very few fossils are found in them, concretions resembling turtles in form when extracted, some vegetable markings and one ammonite, are all I have found.

Cretaceous rocks.

The ammonite is but a sorry specimen, very much flattened and outlines destroyed by pressure, but it is plainly an ammonite, and from it and the character of the succeeding rocks, No. 33, I am inclined to believe that all the inner mountain exposures from this point are cretaceous, and not, I think, of tertiary age.

Faults.

At almost regular intervals the whole of this marine conglomerate covering the inner hill is faulted to the west, the exposed face at each fault being vertical and of considerable height (in one instance over 100′); "slickensides" are numerous, and it is probably because of faulting that the shales No. 31 appear to lie unconformably upon it; as a conglomerate it is peculiar, angular pieces of very hard dark limestone and flints are embedded in a matrix which is evidently the ooze of a not very deep sea, and which has circulated among sponges and angular pieces, embracing them in so firm a grip after hardening that a good blow will fracture both matrix and its enclosures in a straight plane without deviation. It is highly fossiliferous, orbitula and other foraminifera appearing.

Sulphur springs.

A little below the cross-section line are several copious springs of sulphurous waters, which have a temperature of 109° F. at the point of overflow; considerable quantities of sulphur crystals occur in the stalagmite surrounding them. No doubt quantities of native sulphur exist in the rocks below, and very probably the supply of water is obtained by the river losing itself at a higher point of its course, and following a fault which appears near the springs. Further up the hillside are many places where similar springs have accumulated stalagmite with sulphur intermingled in past time.

Petroleum.

Petroleum is found exuding close to the sulphur springs and for a considerable distance up the valley; along the edge of the marine conglomerate there are beds of bituminous deposit (petroleum mingled with gravel and earth) often 15′ in depth, while up the hillsides for 200′ the debris resting on the conglomerate is blackened by old flowings when the river bed corresponded to their levels. The hard compact nature of this conglomerate prevents the river from denuding it, hence the shales next above receive the wasting contact of the river torrent, and thus a continuous lower level is being annually made along the edge of the conglomerate, and the sulphur waters and petroleum naturally seek the lowest and easiest point of exit; this, no doubt, accounts for the old markings referred to.

Besides these bituminous deposits there are in many of the vertical crevices, over a large area, included plates and particles of petroleum which from long exposure have lost their volatile components and have become solid and much like ozokerit in character and appearance.

Crystals.

Within these crevices (and they are abundant) selenite crystals often contain small globules of both solid and liquid petroleum. The slow rate of denudation occurring in this almost rainless district, when considered with the height at which old flowings are found (200′ above present natural flowings), together with the time required for the formation of natural crystals, dimly indicates how long petroleum has been escaping to the surface in this locality. Its rapid disappearance after escapes is owing to its great specific gravity, and to the readiness with which it is converted into a solid easily ground and mingled with the gravels of the river below.

Borings.

There are three trial borings for petroleum, one of which is 524′ deep, of $4\frac{3}{4}''$ diameter. In the deepest of two of these borings (the other is but a shallow one), the following, in order of succession downwards, are the rocks penetrated:—

	Thickness.	Depth.
(1) Gravel, with boulders and bitumen	12	12
(2) Jointed blue limestone	20	32
(3) Hard marine conglomerate with abundance of flint	195	227
(4) Alternating bands of soft bluish shales and hard flinty limestone with iron pyrites.	30	257
(5) Rather hard shales with pyrites	217	474
(6) Dark grey limestone without fossils	2	476
(7) Soft grey shales	48	524

Oil was obtained at 28′, at 62′, at 92′, at 115′, at 125′, at 133′ and at 374′.

Rocks creviced.

The conglomerate is broken and fractured in all directions, and through these the oil finds its way upwards, borne on the top of the warm waters which accompany it, but while these fractures afford a ready means to the miner of "striking oil" they sadly interfere with his progress in boring, as the drilling tool in descending must inevitably enter many of these crevices at an acute angle to their planes, and it is almost impossible to prevent the tendency of the tool to follow the vagaries of such crevices and thus produce a "crooked hole," which is fatal to further progress unless straightened. It is, all round, the most difficult of rocks in which to construct borings the writer has yet encountered.

Character of the oil.

A report of the character of the petroleum obtained here has, in 1884, been sent into the Government of India, and I need only add that owing to infinitesimal particles of sulphurous and acid waters being held in suspension within the oil, it is most difficult to distil it. These particles in the process of distillation are vapourized at a little over 212° F., while the oil vapourizes at over 306° F.; the consequence is the vapour first created causes the oil to foam within the still, and finally carries it over with it into the condensing pipes bodily, which operation is known to refiners by the inelegant term "puking." The remedy lies in a specially constructed still, or a mechanical appliance in ordinary stills for beating down the foam, or by a chemical process for removing the waters before distilling is undertaken.

At present about 1,000 barrels of crude oil are being sent to Sibi, for a thorough test as to its suitability for locomotive fuel.

Gas.

Both in drilling and pumping the borings, a considerable quantity of sulphuretted hydrogen gas is evolved, but it is not in sufficient quantities to cause a natural flow of oil from the tubes. In pumping the oil from the show obtained at 374′ we found that it came up with the warm water in very small globules, thoroughly mingled with and giving the water the appearance of having had snuff thrown into it; at rest the oil and water soon separate and the water becomes clear.

Theory.

It has occurred to me as a tenable theory that the petroleum of this locality may be produced by the action of sulphurous acid waters combined with alkalies, all at a moderately high degree of heat acting chemically upon a deep deposit of coal, or lignite, under confinement, and it may be that all petroleum has a similar origin. It is a fact that all producing oil-fields are in strata containing sulphur, salts and alkalies. The Canadian and American fields both retain inexhaustible supplies of saline sulphurous waters, some of them sufficiently strong to destroy in a few weeks the iron tubing used in pumping.

Economic rocks.

Besides petroleum there are no products of economic value here. If works were established for the manufacture of oil it is possible that saltpetre, alum, and alkalies might be produced at a profit from the manipulation of the shales. Of gypsum there are endless quantities of excellent quality, but too far from any market, I fancy, to export at a profit. The entire country round about is barren, save a few tamarisk and other scrubby trees, and a few acres of cultivable land. All the waters available for domestic use are charged with sulphate of lime and do not conduce to one's health.

G. I. C. P. O.—No. 28 D. G. Survey.—23-9-86.—230.

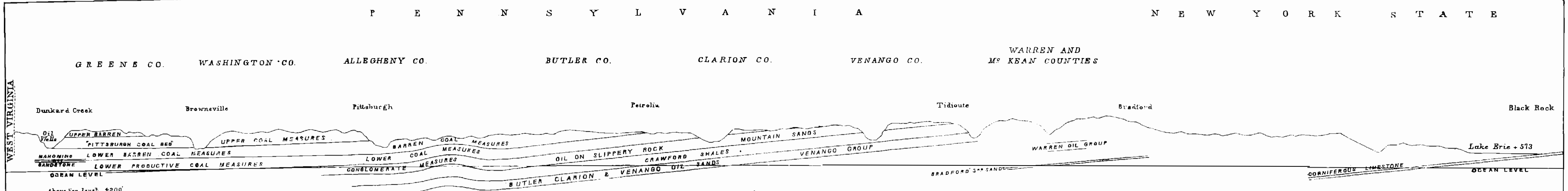

Fig. 1. Mr J. F. Carll's section of the Pennsylvania oil measures.

Length 225 miles. Scale: Vertical, 1" = 3500 feet: Horizontal, 1" = 50000 feet.

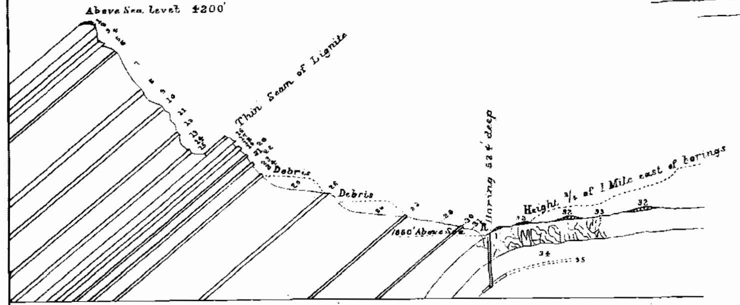

Fig. 4. Mr R. D. Townsend's section of the Khátan oil springs.

Length 7200 feet. Scale 4" = 1 mile.

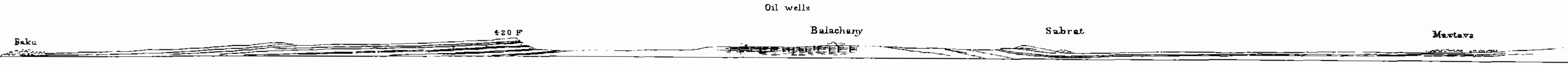

Fig. 2. Professor Abich's Section of the Baku oil measures.

Length 16 miles. Scale 1" = 1 mile.

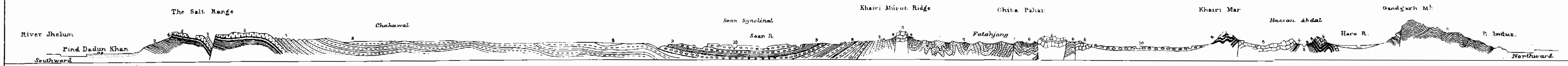

Fig. 3. Mr A. B. Wynne's section of the Punjab oil region. Length [illegible] miles. Scale 1" = 5 miles.

References: 2 Lower Palæozoic, 3 Carboniferous 4 Mesozoic, 5 Lower Nummulitic, 6 Upper Nummulitic, 7 Nahan, Sirmur 8 Lower Siwalic, 9 Upper Siwalic, 10 Old Gravels.

On Stone by Aminullah