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*Note on the occurrence of* petroleum *in* India, *by* H. B. Medlicott, *Geological Survey of India.* (With two plates.)

## Introductory.

There is very little indeed to be added to what has been already published upon this subject; but occasion demands that it should be noticed in connected form and under the light that has within the last few years been generated by experience in other regions. From the nature of the case this note will be chiefly made up with illustrations from abroad, as a clue to what may be looked for in India. The extension of railways on all sides has brought up a vote of urgency on the question of fuel, and our masters (through the press) are asking, 'What is the Geological Survey about?' The answer to this question has been within easy reach of those who chose to seek for it in the publications of the Survey. Years ago the little that can be learned from surface examination regarding the habitat of petroleum in India—in Upper Burma, Pegu, Arakan, Assam, and the Punjab—had been set forth, and until the fulness of time there would have been no use in repeating it. It is the practice of British Government at home to leave everything as far as possible to private enterprise, and it is not rightly understood that a total change of environment requires a change of system. The Survey is not equipped for or expected to carry out experiments, and without these on a more or less extended scale there was nothing further to be said upon the local conditions of petroleum. Now, however, thanks to our Russian friends, things have improved: the great extension of railways in North-western India and the scarcity of fuel there, have led to official investigations as to the hidden resources of that all-important material.

2. Already some success has been achieved in that direction, through the determination of Sir Theodore Hope, the Public Works Member of Council, to test the often-condemned coal of the Salt-range. Those nummulitic coal-measures had been repeatedly described and reported on, and provisionally pronounced to be unprofitable. They are well exposed throughout an immense stretch of country from north of Jamu in the Sub-Himalayas, through the Salt-range and the Suliman range into Sind. The strongest outcrop has been observed in the Jamu hills, far inside the fringing Siwaliks, but in that ground the measures are terribly broken and crushed. In the Salt-range they are of average development

and somewhat favourably placed for working. To the south they still further deteriorate, as seen at the well-known outcrops of Mach, in the Bolan pass, and of Lynyan in Sind. Other outcrops occur well to the north of the Salt-range, south of Attock in the Chita Pahar hills, where some money was lately wasted on exploration. In all these exposures, on very different strikes, the seam exhibits the same feeble development, which is certainly strange considering the very wide range of the coal-forming conditions here at that time; but from the abundant observations it was evident that no hope could be given of its improvement in any direction. The recent exploration in the Salt-range has not affected that judgment. As was to be expected, it has been proved by borings that the coal, such as it is, occurs under a considerable area in the Dandot plateau, easily accessible by drifts, so as to be economically workable under present conditions. A large consumption of imported coal at 3£ a ton would bring any sort of local supply into requisition. The best prospect, though not a very hopeful one, of a permanent supply of coal in this region lies in Mr. Oldham's recent announcement of the possibility of a field of Gondwana measures in Eastern Rajputana.

3. The same need has brought the petroleum question to the front, and the Government have begun explorations where the demand is most urgent, and with fair preliminary success. It is right to mention that this matter has not been neglected in the past: it was taken up seriously nearly twenty years ago, and an 'expert' was imported from America to examine the oil-bearing rocks of the Punjab. His reports were published in 1869-70; they were not encouraging, so the enquiry dropped. That mishap was to some extent due to the popular confusion on the genus 'expert'; and under present arrangements our rulers are of course only magnified representatives of popular notions. Operative (practical) functions are almost invariably connoted by the word 'expert'; and it would be well if the term could be confined to that sense, for though there is no essential reason why the scientific specialist should not be called an expert, there are marked distinctions between the two species, and the confusion of them is often fatal. When a man has to be hanged it is important that an expert should operate; but it would be a mistake to consult the hangman upon a puzzle in criminal law. Yet in matters mineral this error is continually committed by business men as well as by those who ought, at least through faith, to know better. The illustration from the course of law does not even sufficiently mark this blunder in mineral concerns; for here the defect is not only negative but positive—the man whose skill has been acquired in dealing with one group of conditions is actually led astray thereby in giving an opinion upon other conditions, his knowledge being solely empirical. Mr. Lyman's judgments seemed unduly cautious, or even partly erroneous, as I had occasion to point out three years ago when consulted in the matter.[1] There is, however, much excuse for anything that may have been said or not said even sixteen years ago on this subject, for although the petroleum business was then in full swing, the information derivable from such hasty experience had not been brought together. Even now the guidance to be obtained is most precarious; but the reason of it lies in the protean

[1] See Supplement to the *Gazette of India*, October 20, 1883, p. 1717. There is a misprint on the tenth line: for *holes* read *beds*.

character of petroleum itself. A little consideration of familiar facts will satisfy the incredulous that this excuse is not a professional subterfuge.

4. In these days of graphic papers, every one is familiar with the wonderful performances of the spouting wells of Baku and Pennsylvania. They form the popular standard of what a petroleum well ought to be. This is unfortunate; but a very little reflection on the fact thus plainly displayed ought to furnish the needful antidote to that hasty inference, and lead to a rational conception of what must be the variable and inscrutable distribution of petroleum. It needs no argument to show that a light and slippery fluid, which gushes out at the surface under a pressure of 300—400 pounds to the square inch as soon as tapped by a bore hole, would certainly not have stayed where it was if it could possibly have escaped, and that it would infallibly distribute itself under ground according to the access afforded by the permeability of the surrounding rocks. That pressure is not hydrostatic, as in artesian springs, communicated from a higher level within the same closed basin: it is elastic pressure, due to the expansive force of the gases that are always generated with the oil, so it is self-acting, independently of any structural arrangement of the enclosing rocks, although it is, as we shall see, controlled in many important ways by that structure.

5. Any useful knowledge we can have of mineral deposits depends on what we can discover as to the conditions of their origin and history, and for all minerals more or less of such knowledge can be attained; for petroleum, however, this knowledge is of little avail, because owing to its mobility it does not abide in its birth-place, but slips about in the most insinuating way wherever it gets a chance. It is something to know that there is a dominating effort to ascend; though of course, when the upward passage is barred, the oil would penetrate sideways or downwards under the elastic pressure of the gases which always accompany it. It would be easy to follow out these *a priori* considerations in connection with the familiar facts of stratigraphy, but the application will be better exhibited in actual examples.

## NATURE AND ORIGIN OF PETROLEUM.

6. A real acquaintance with petroleum would require initiation into the mysteries of organic chemistry, for it is as protean in its composition as in its modes of manifestation; but it is desirable to have some notion of the substance under discussion. Homogeneous as it seems, petroleum is made up of an indefinite number of distinct compounds of carbon and hydrogen, or hydrocarbons; they are gaseous, liquid, or solid, and seem to co-exist in the crude material, for they are separable from it, without what is understood as decomposition, by careful fractional distillation and by treatment with appropriate solvents. The most important of these series of compounds are the saturated hydrocarbons known under the family name of the paraffins, represented by the general formula $C_n H_{2n+2}$. It begins with marsh-gas, $C H_4$, in which $n = 1$; descending, by the gradual increase of the carbon, with a corresponding increase of density, to the solid forms, the paraffins proper. Molecular science has scarcely yet mastered (or at least simplified) the intricacies of these compounds: within the several series there are numerous isomeric forms, *i.e.*, distinct substances whose empirical formulæ are identi-

cal, also polymeric bodies whose formulæ are integer multiples of the same primitive group. The volatile (inflammable) properties naturally increase with the proportion of hydrogen; but it is evident that specific gravity would be no safe guide on this point in a mixed oil, for its inflammability might be determined by the presence of a very small proportion of a lighter oil. Bitumen is the name in most general use for this whole class of substances. The solid forms are distinguishable from coal or other like matter by being fusible, and by their complete solubility in bi-sulphide of carbon. As occurring in nature the solid forms are called asphalt, while the more fluid forms of petroleum are distinguished as naphtha, and the more viscid, tarry kinds as maltha. The manufactured products have a like classification: there are the naphthas, principally used as solvents; the less volatile distillates are the burning oils; the thicker kinds are much used as lubricating oils; the residual solids are paraffin, naphthalene, anthracene, &c. Petroleums differ much in the proportions they yield of those different products; *e.g.* the California bitumen contains no paraffin, it also holds a small proportion of nitrogen; both facts have suggested the probable derivation of that petroleum from animal matter.

7. It is also desirable to know something of the supposed origin of the bitumens; and the questions are, whether or to what extent they are connate, or innate, or introduced, in the situations where they are found. They would seem *primâ facie* to be allied to coal: yet the essential dissimilarity of the two is what opens the door of speculation regarding petroleum. We commonly speak of 'bituminous coal'; but it is incorrect, as coals contain little or no bitumen, although bitumen can be obtained from them by destructive distillation, leaving a large residue of coke. The production of these oils in this way from shaly coal (unfit for furnace use) and from coaly shales, or 'oil-shales,' formed a very extensive industry before the petroleum discoveries set in, and it is still flourishing: the production last year in Scotland alone amounted to 62,712,000 gallons of crude oil. The origin of coal may be said to be completely known: by the slow transformation *in situ* of vegetable matter through the slow combustion of its less stable elements, producing a constant concentration of fixed carbon, with less and less of hydrogen and oxygen. It is found in every stage of transition from turf and carbonized wood down to anthracite, in which only the carbon remains. This process is completely natural and intelligible, and the puzzle is how in the case of petroleum, if it had an analogous origin from organic matter, the exactly opposite result—a concentration of the hydrogen element—can have been brought about, for the two are commonly quite similarly located and not seldom associated in the same series of strata. The contrast is exhibited by a comparison of their composition with that of cellulose, which is the basis of vegetable tissue—

| | Carbon. | Hydrogen. | Oxygen. |
|---|---|---|---|
| Cellulose . . . . . | 44·4 | 6·2 | 49·4 |
| Ordinary coal . . . . . | 84·6 | 5·6 | 8·0 |
| Petroleum . . . . . | 85·0 | 15·0 | |

8. This difficulty seemed so forcible that the connection of petroleum with organic remains has been denied and its origin as truly a mineral oil asserted. In 1862, the distinguished French chemist Berthelot succeeded in producing several of the familiar hydrocarbons by various processes, such as by bringing steam and carbonic acid into contact with highly heated metals having a strong affinity for oxygen. Conditions of this sort being reasonably assumable as occurring at great depths underground the possibilities of the theory were furnished, and it was strenuously sustained in the field by an able geologist, M. Coquand, from his study of the petroleum deposits in Roumania and Albania.[1] As against an organic origin he considers it final that no residual carbon is found with or near the petroleum; but while attributing the oil to a wholly independent source he insisted upon its contemporaneity with the deposits in which it is now found; he asserted that in all times, as now, petroleum found its way to the surface and there necessarily mingled with whatever deposits were being formed in the neighbourhood of its discharge. Under this view the oil would be in a half sense connate with the beds containing it, although provided ready made from a remote source. This is more or less plausible; and in the famous bitumen deposits in pliocene gravels at Selenitza in Albania, where the mineral has been extracted for many centuries, he seems to prove a deposit of this nature, such as might now be formed at the Pitch Lake of Trinidad, or elsewhere; but he insists on the same process for the petroleum of Roumania, where the oil occurs in two zones of stiff blue clay of eocene and miocene ages. The contemporaneity of the oil (or its elements) with the deposits seems undeniable, for although the rocks are much disturbed the oil keeps constant to the same beds, and it is hardly possible that it could have been injected into stiff clays after their consolidation; but it does not occur to him to explain how, under this theory, a comparatively light fluid was not floated away by the depositing waters. This objection however recurs, though in a less degree, for any theory of contemporaneous deposition. M. Coquand had a block of the fresh clay brought up from the pit for examination, and he found that the oil was not diffused through the mass, but distributed in little patches with thread-like connections.

9. The difficulty of petroleum being *innate* (by metamorphism), like coal, from organic remains in the beds where it is found, is equally admitted by those who deny its purely mineral origin: the apparently necessary residuum of carbon cannot be spirited away by theory. A considerable step in the coal-forming process is made in the decaying vegetation as it accumulates under more or less free access of air; a further great step is accomplished under a comparatively light covering of later deposits, and there is no stretch of imagination in supposing that gradual increase of pressure and temperature can accomplish the rest, the escape of volatile elements being all that is needed; but no plausible conjecture has been made for the removal of the surplus carbon or for its conversion by the access of free hydrogen, to form petroleum out of the same elements as coal; it has therefore been urged that this substance is *connate*, not innate. An apparently plausible conjecture on this side is, that petroleum is derived from marine

[1] Bull. Soc. Géol. de France, (3) Vol. XXIV, (1866-67), pp. 505–569; and Vol. XXV (1867-68), pp. 20–74.

vegetation, as coal is exclusively from land plants; and that the slow maceration it is subjected to during deposition under water may produce the required result. This view was well put forward by Mr. Leo Lesquereux in 1866.[1] He remarks that Algæ thrown upon peat do not leave any trace of organism, but the resulting compound is softer and of deeper colour; that Algæ heaped upon the shore promptly decompose into a soft black paste and then into a glutinous fluid which sinks into the sand; he even appeals to the green fat of turtles as derived from a diet of Algæ. He also refers to the frequent occurrence of petroleum in strata with fucoidal impressions. He regrets that Liebig was unable to supply him with any hints upon the chemistry of the process. Dr. Sterry Hunt, who is especially an authority on the chemical side, adopts this view in a general way.[2] He admits that the origin of petroleum may be referred to a particular transformation of organic matter effected in deep water where calcareous deposition is in progress, while similar matter in shallow waters loses a larger proportion of its hydrogen and forms coaly deposits (pyroschists). He alludes to the great bank of *Sargassum* in the Mid-Atlantic as a probable seat of such production.

10. It is true that Mr. G. P. Wall,[3] from his examination of the bitumen deposits of Trinidad, of which the famous Pitch Lake is but a waste-pool, satisfied himself that the asphalt is innate, being formed from the remains of terrestrial vegetation in the shaly sand where it occurs. He attributes its accumulation as irregular masses in the bedding, and the consequent loose texture of the shales, to the segregation that took place after the conversion of the diffused matter into bitumen. To account for his opinion he accepts as actual Bishoff's formulæ[4] showing how by giving off carbonic acid instead of carburetted hydrogen fossil wood might turn into bitumen instead of into coal; but there is something to be desired in his demonstration that such was the case. The evidence that has been principally quoted is Mr. Crüger's admirable study of some specimens of wood more or less changed into bitumen, but Mr. Wall does not show how far these were representative of the deposit, or that all the specimens may not have been what Mr. Crüger (*l. c.*, p. 175) says some of them were, simply "rotten wood impregnated with pitch." There are lignites associated in the same upper tertiary deposits with this asphalt.

11. There remains the question whether petroleum may not be an interloper in its present locations. That it is so in some cases is beyond question, for it is found in force filling fissures in eruptive and crystalline rocks; and it goes without saying that since it reaches the surface it may (or must) take possession of any convenient receptacle it comes across in its ascent. This theory has thus a certainty to start with; and we shall see that it is as good as proven that the greatest known sources of petroleum were formed in this way—that the oil was not indigenous but introduced where now found. The question of origin remains open: whether by direct synthesis from mineral elements, or by distillation from fossil organisms; the conditions of distribution would be to some extent the same

[1] Transactions of the American Philosophical Society, Vol. XIII, (N. S.), pp. 313—328.
[2] Bull. Soc. Géol. de France, (2) Vol. XXIV, p. 572 (1867).
[3] Report on the Geology of Trinidad: Memoirs of the Geological Survey (Colonies), 1860.
[4] Chemical and Physical Geology, Vol. I, pp. 281-88, (1854).

in either case. The distillate theory has been rather unfairly handled, the chief bone of contention being again the irrepressible carbon residuum. Because coal and pyroschists are found in their normal state in close proximity with petroleum, because the residual carbon is not found with or close by the oil, the possibility of derivation by distillation is denied. Or again, because all the rocks below a petroleum bed are not smudged with oil, the possibility of its having come from below is rejected. This latter difficulty is the least reasonable, as it assumes that the distillate would take the most difficult route to reach its destination, namely the direct one, across the bedding of the intervening rocks. Underground water does not percolate in this fashion, and why should petroleum, whether as liquid or as vapour? In the latter case too it seems clear that it would not be precipitated until it found its appropriate condenser, and there seems no limit to the circuit or the distance it might have to travel before reaching that resting-place. Then as regards the great crux, it should be remembered that there *are* immense stores of residual carbon in the older stratified formations, whether in the state of anthracite or of graphite, both massive and diffused. It can hardly be demanded that it should appear in the form of coke: it seems presumable that after all the oxygen of coaly or other organic matter had been eliminated, the final step in the production of anthracite or graphite, under the influence of gentle heat, would be the evolution of hydrocarbons. It has moreover been suggested that for marine animals and plants, which together supply no doubt the chief bulk of fossil remains, the proportion of carbon to be accounted for is much less than in the land vegetation forming the basis of coal. It is to some such action as this that Mr. Carll appeals as the origin of the great oil deposits of Pennsylvania which he well nigh demonstrates not to be indigenous (either innate or connate) in the deposits where it accumulated. As an objection to making this process universal, if so foolish an attempt were made, one might urge the impermeability of some rocks in which petroleum is found, such as the stiff clays of Roumania already referred to, or the occurrence of oil in the cavities of fossils in the midst of a dense limestone. Both these instances have reasonably been taken as evidence of indigenous origin; but indeed, when we find geodes filled with successive layers of minerals in the midst of compact basalt it is difficult to place limits upon the possibilities of permeation.

12. The foregoing notice of the current speculations regarding the origin of petroleum should be of some service, if only to explain the uncertainty that must exist as to its distribution in any particular locality. With so ample a store of raw material as is provided by fossil remains in the prodigious accumulations of stratified rocks; also, with the agency of conversion, by slow increase of pressure and temperature, provided in the changes to which those rocks are in every degree subjected, there is no excuse for appealing to the more or less occult resources of the earth's inner laboratory, so this view of the origin of petroleum as a 'mineral oil' has been generally abandoned, though it might be rash to assert that no such phenomenon ever took place. The fact that in its most prolific deposits the oil is not indigenous is the most salient result of past experience; but it is fully accepted that in some deposits it is so, and such is evidently a corollary of the approved mode of origin: the compulsion to leave its birth-place would be an

extra exercise of the conditions that brought about its formation; in many cases it would only be the surplus product that would have to find accommodation elsewhere.

### The Pennsylvania oil region.

13. The most extensive and most productive petroleum region as yet worked is that stretching as a long belt from Canada into Tennessee west of the Appalachian mountains in eastern North America. The total area of this region is estimated at 200,000 square miles. The great series of palæozoic formations, which have been crumpled up to form the mountain range, are practically undisturbed in the oil region, having only a gently undulating inclination, averaging 25 feet in the mile, in a south-westerly direction. In 1885 the yield of oil from this region was 21,600,000 barrels (of 42 gallons each), from 20,000 more or less productive wells. The richest fields occur in Western Pennsylvania, and a full description of them, by Mr. J. F. Carll, was issued by the Geological Survey of Pennsylvania in 1880. The section in figure 1 of the annexed plate I is reduced from one given in that work. It represents a distance of 225 miles. The vertical scale is 20 times that of the horizontal scale, so that the apparent dip of the strata is much exaggerated. The accumulated thickness of the formations amounts to 6,400 feet, extending from the upper coal-measures in the south-west down to the corniferous-limestone (bottom devonian), which forms the Black Rock outcropping in the Niagara river just below Lake Erie. In Canada this rock passes again underground and is the principal source of the Canadian petroleum; but oil is found at a much lower horizon, in the Trenton-limestone (lower silurian), where there is no underlying fossiliferous rock—a fact insisted on by Dr. Sterry Hunt as proving that the oil must be indigenous in this limestone. In the same contention this authority also shows that the Niagara-limestone (upper silurian) of Chicago at its outcrop still holds 4·25 per cent. of oil diffused in its substance.

14. Four principal oil groups are represented in the section, within a thickness of about 4,500 feet of strata, from the Bradford-sand in the north-east to the Mahoning-sand in the south-west. There are several other productive bands of less importance. The groups of strata in which these oil beds occur are more or less continuous over very large areas, the productive oil beds in each being much more restricted. In all cases these beds are sands and gravels, the output of the field being proportional to the porosity, thickness, and extent of the 'oil-sand.' These are very variable and irregular elements, as is always the case with coarse deposits. The thickness of an oil-sand has been found to range up to 120 feet. Owing to the innumerable borings that have been made, perhaps most of them without success,[1] the horizontal distribution of the several oil-sands has been very closely fixed; they mostly have an elongated shape, as is the habit with sand banks. The Bradford field covers about 133 square miles. In every case the oil-sands are overlaid by fine impervious shales. Throughout the greater part of the oil region there was little or no surface indication of the occurrence of oil in the ground, though, of course, such did appear at or near the outcrop of the oil-rocks. The

[1] Amongst these was the deepest well yet sunk in that region—Watson's Well, at Titusville, 3,553 feet deep, of which 2,263 were below ocean level.

most productive sources were, as might be expected, at a distance from where a natural escape had been effected.

15. From the facts before us it is plain that the distribution of the petroleum in this region has very little to say to geological horizons in their particular (chronological) sense; but Mr. Carll notices an apparently important feature in its vertical distribution. He remarks that all the productive measures occur within a level zone of 1,500 feet; that although a large number of deep holes have been put down none have produced oil at a depth of more than 500 feet below ocean level, and very rarely at more than 2,000 feet from the surface.[1] Gas on the contrary appears here to be a universal product, confined to no particular horizon or locality (*l. c.*, p. 111). These facts *primâ facie* suggest that the position of the oil was determined by a zone of condensation and of catchment of volatile products distilled from underlying rocks. The particular conditions would agree with this interpretation: coarse sand banks are the least propitious ground for the accumulation of organic matter, while such matter is known to be present abundantly in the shaly and calcareous strata underlying these oil-measures to a great depth. The notion that the oil occurs in crevices and cavities has not been confirmed by observation in this field; the porosity of the sands themselves is sufficient. Mr. Carll is careful not to propound these observations as of universal application, and it is obvious to the geologist how certain conditions might alter the figures of the problem, but it is certain that the results are the most important contribution as yet made to the question in hand. It is now generally accepted as proven that for the most part the petroleum with which the 'pools' of the eastern North American basin were so copiously charged, was not indigenous in those 'oil-sands.'

16. It is of greater importance for us to notice how essentially the wealth of these oil measures depends as much upon their actual as upon their original stratigraphical conditions—on the fact that the strata are still practically undisturbed. The formation of these pools depended upon the prior formation of the more or less isolated lenticular banks of sand and pebbles, and upon these being more or less hermetically covered by finer deposits; but the preservation of them depended no less upon that favourable arrangement being undisturbed. The permeability of strata is incomparably more easy along than across the bedding; an almost imperceptible film of finer deposit might exercise a very important control upon the circulation of fluids underground. It is evident that when strata become tilted and broken, the conditions of circulation are wholly altered; porous beds that before were lying flat, and safely covered over, become turned up and brought within easier reach of denudation, whereby they expose outcrops at the surface; or cracks are more or less abundantly formed, offering egress where before there was none. A fluid under elastic pressure must avail itself of such means of escape from its original prison-house. These conditions have been fully recognised in practice: in a paper read before the American Institution of Mining

[1] Mr. Carll (*l. c.*, p. 151) further emphasizes the fact that two oil groups are never found in the same vertical: the Warren group has never been found directly beneath the Venango group, nor the Bradford oil-sand directly beneath the Warren group. It is not quite clear whether only the oil is wanting, or also the sand beds: as only the former case would be 'remarkable' in this connection it is presumed that this is intended.

Engineers in September 1885, Mr. C. A. Ashburner, Geologist in charge of the Pennsylvania Survey, remarks—"That the absence of both petroleum and natural gas in our plicated strata east of the oil-regions is to be explained by the cracking of the rocks would seem to be evident, since the survey of the outcropping rocks and a study of the records of dry wells show that the oil- and gas-sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil and gas-wells have been found the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities."

17. Very partial disturbance, such as these measures have undergone, may even help the concentration of the oil, which would naturally rise to the highest part of a bed that had undergone slight tilting or curvation. Hence the craze that so long prevailed regarding a connection of oil with anticlinal axes. To a certain point it is true enough; but on the other hand an anticlinal axis is the most likely position for fractures, and even were the rocks not broken this position is obviously the one to be soonest exhausted.

18. Although the immense energy displayed in developing the industry of the oil fields under notice has given us data for a fair understanding of their structure and extent, it is lamentable that some check was not put upon the prodigious waste of those great natural and national resources through the reckless competition of greedy adventurers. Forests are protected, although renewable; but in mineral resources, which are limited quantities, it is among men and nations a race of 'devil take the hindmost' in squandering all that can be laid hold of, heedless of the waste caused by the scramble. The most prolific of gushing wells ere long settle into pumping wells; the average life of wells in Pennsylvania is five years. Already there is notice of coming exhaustion in this great region: last year on the occasion already quoted, Mr. Ashburner remarked—"That the general boundaries of the oil regions of Pennsylvania are now well established, there is but little doubt; and that all the sand in which oil will ever be found in paying quantities are known and have been drilled through at different localities in the oil-regions seems quite certain, so that we can have no reasonable expectation that any new and extensive field will be found which could compare in area or in the amount of oil to be obtained from it with the Butler, Clarion, and Armstrong pool, the Oil City and Pleasantville pool, the great Bradford pool or the Allegany pool. * * * It is estimated that in July 1883 there were in the region 17,000 producing wells, the average daily product of which was 3·8 barrels. In July 1884, there were 21,844 producing wells, and the average daily product was 3 barrels; and in July of this year [1885] it is estimated that there were 22,524 producing wells, the average daily product being 2·5 barrels. A defined territory, a product inadequate to meet the demand of the market for the past eighteen months, a growing market and rapidly diminishing stocks, an increasing number of drilling and producing wells, and a rapidly falling daily average product from wells, are all significant signs of a certain decline in a great industry."

## Baku.

19. The only known petroleum region at all comparable as to productiveness with the great American basin is that of Baku, where the range of the Caucasus

ends at the Caspian sea in the peninsula of Apsheron. It will be instructive to see in what other features these unparalleled oil measures are alike. The geological information regarding the Baku ground is comparatively scanty, because, notwithstanding the prodigious output of oil, the workings are still limited within an area of five square miles. The wells too are of very moderate depth, the deepest as yet being only 840 feet.[1] This would seem to warrant the judgment that this spot can only be the natural focus of a very extensive oil region. In geological age the two measures are about as different as they could be, the American rocks being lower palæozoic, while those of Baku are middle tertiary; but we have already seen that the geological horizon has little to say in the matter. The rocks too are quite dissimilar, beyond the common characters that clays, sands, and limestones of every age must exhibit. The oil at Baku is held in irregular banks of sand between strong beds of clay, with some limestone. The critical feature of resemblance is that at Baku also the measures are nearly horizontal, and there can be no doubt that the profuse abundance of the supply is immediately due to this condition, and that the oil in these sands is accumulated from underlying or adjacent rocks. The strata, so far as visible at the surface, are remarkably wanting in organic remains. In figure 2 I have reproduced Abich's section of the Apsheron peninsula at the oil wells, from which it is plain that these are situated at the crest of a very flat anticlinal. The section is copied from the Mémoires de l'Académie des Sciences de Saint-Pétersbourg, Ser. vii, Vol. vi, of 1863, but it is quoted up to date as the authority, for which Abich's name is sufficient guarantee. The present (1885) annual output at Baku is given as 1,000,000 tons; the 100 wells now active yielding an average of about 32 tons per day. A single well has given as much as 140 tons a day for ten years, the oil standing at 51 feet from the surface; it ultimately failed altogether. Here too incipient local exhaustion has been noticed; in a paper in the Mining Journal of St. Petersburg for September 1885 Mr. F. Vasilieff mentions a marked increase in the proportion of water admixture,[2] indicating exhaustion of the oil; but in this region it would seem likely that there is ample room for extension.

### COMPARISONS.

20. In every other description I can find of petroleum diggings all over the world, so far as intelligible, they differ from the two leading cases already given, in the circumstance that the strata are much disturbed.

21. The further exploration of the Punjab oil measures has recently been vigorously urged upon the Government by a distinguished officer, who has been ten times at Baku and made a special study of the petroleum workings there, and who has also examined the Punjab oil measures. His recommendations are based upon the striking similarity of the two fields. He observes that "unless a geologist or expert had actually visited the petroleum wells at Baku, I should not value his opinion for the reasons that I perceive a striking resemblance

[1] Vasilieff: September 1885.

[2] As this water is probably flooding water (from above), the symptom is not so bad as it might otherwise be.

between the country and soil near Gunda and that which forms the Aspheron peninsula." To illustrate this remarkable observation I have reproduced in figure 3 Mr. Wynne's section of the Punjab area, from Vol. X (1877) of the Records of the Geological Survey. It crosses the very place mentioned (Gunda) at a short distance north of Fatehjang; the oil occurs in the nummulitic strata, numbered 5 and 6. A comparison of this section with those of figures 1 and 2 will scarcely bear out the 'striking resemblance' asserted in the quotation just given: the oil measures of the Punjab are about as much disturbed as rocks can be, which fully accounts for the state in which we find the oil; for ages it has had free vent at the surface, the only check being the porosity of the containing strata. If the example quoted from Mr. Ashburner of the American oil measures as represented in the flanks of the Appalachians, were to be hastily taken as a precedent, there would be little hope for the Punjab oil; but the cases are not quite parallel, and with petroleum no precedent would be safe. Besides we have here the crucial fact that there is still oil in the ground, notwithstanding the exhausting conditions of the Punjab climate. But any prospect of even a distant approach to the Baku standard must, I think, be given up. All the Indian oil measures are in about the same geological horizon (eocene) and in much the same condition as to disturbance, the Irawadi region least so; but they vary greatly in apparent fruitfulness, the Punjab region being decidedly the least promising.

### Californian region.

22. I have searched all the accounts I could find of the occurrence of petroleum in disturbed measures, for any hints that might be of service in exploring our Indian rocks, but with very little success. This is not surprising when uncertainty in every condition is the rule. Such works are moreover incomparably less extensive in every way—in area, in the number and depth of the workings—and have consequently received less attention. In America the next most important measures, but far inferior, to those of the Appalachian basin are found in the tertiary rocks of the coast ranges on the Pacific, chiefly in California. Information on this ground is very scanty. Even in the elaborate report on petroleum, drawn up by order of Congress for the tenth census of the United States in 1882, Mr. S. F. Peckham mentions the extensive operations of the Pacific Coast Oil Company, but regrets that he was unable to obtain any particulars in reference to the production of their wells. He has to refer to results in that region generally as confirming the opinion he had expressed after his exploration there in 1866, that "the expectation of extraordinary results, that will admit of comparison with those produced in Pennsylvania, must be set aside. The expectation of a fair return and a permanently profitable investment may be reasonably entertained; and the application of capital on this basis to this interest will make it of great importance to the State." The measures seem to lie chiefly in mountainous ground, in very disturbed rocks. There are frequent deposits of asphalt and of maltha at the surface from the evaporation of exuded petroleum. Even underground this effect is observed, and to be in direct proportion to the ease with which rain-water could percolate the strata. The oil primarily occurs in strata of shale, interstratified with sandstones of enormous thick-

ness. Mr. Peckham mentions that he "nowhere observed the petroleum saturating the sandstone, although it sometimes escaped from crevices in it; nor was the bitumen held in crevices of large size nor under a high pressure of gas, as the disturbed and broken condition of the strata, folded at very high angles, precluded such a possibility." He considers the oil to be indigenous (innate) in the shales. In hilly ground, and in such rocks, the oil is often got at by tunnels, or drifts, for which practice a synclinal structure of the strata in the range is obviously the most propitious. The exploitation of this oil region is at present evidently held in abeyance by the profuse output of the eastern region; still Mr. Peckham estimates the yield for the census year at about 1,000,000 gallons.

EUROPE.

23. The most productive oil-ground in Europe seems to be along the flanks of the Carpathians—in Galicia, Roumania (Moldavia and Wallachia), and Transylvania (Siebenbürgen)—where of course it has received due doctorial attention. Mr. Redwood[1] notes the production of crude petroleum in Galicia for 1883 as follows:—

| | Cwt. |
|---|---|
| West Galicia— | |
| 1. Sandez and Gorlice | 91,500 |
| 2. Jaslo and Sanok | 44,900 |
| East Galicia— | |
| 3. Sambor and Drohobyez | 73,600 |
| 4. Kolomea | 300,000 |
| | 410,000 |

There were then 3,500 producing wells. The third district produced in addition 105,200 cwt. of ozokerit (crude paraffin wax). The most productive ground of the Kolomea district was not opened until 1881, and at the end of 1883 it was reported to be yielding 550 barrels of oil per day within an area of 1,500 metres in length and 350 to 500 metres in breadth. The number and depth of the wells are not given. The oil-measures of Galicia occur at several different horizons in cretaceous and tertiary rocks: some of the latter correspond with those of India, and all are, like these, in highly disturbed strata.

24. In 1859 M. F. Foetterle[2] mentions that in West Galicia many wells, over 60 feet deep, produce at first the "not inconsiderable quantity of 12 gallons in half a day," the other half being apparently allowed for accumulation; the oil is skimmed from the surface of the water with which it percolates to the well. The oil comes from the crevices in a much shattered black bituminous shale interbedded with sandstones (eocene). He attributes the gradual decline in the yield to the slow natural process of production, which he assigns (without explanation) to the action of decomposing pyrites sparingly disseminated through the carbonaceous shale, under the influence of atmospheric agencies. Mr. Foetterle describes the wells at Boryslaw and Truskawice in East Galicia as in somewhat newer rocks in which the oil completely saturates a soft sandstone.

[1] Petroleum and its Products: Journ. Soc. of Arts, Vol. XXXIV (1886), p. 813.

[2] Jahrbuch d. k.k. Geol. Reichsanstalt, Vol. X: Verhandlungen, p. 183.

25. Dr. von Hochstetter[1] describes the principal oil tract in West Galicia as about 14 miles long (E.—W.) by 1 mile broad, near New-Sandec; the others being some 40 miles further east, on the same strike. They appear to correspond more or less with the menilite zone (middle eocene), so called from the frequent nodules of menilite (a semi-opal). It is an undulating hill country, some 2,000 to 3,000 feet in elevation, forming a broad belt between the Carpathian axis and the alluvial land on the north-east. The rocks are massive sandstones with alternating sandy shales and marly clays, all steeply folded. The wells are from four to eleven fathoms deep, the sinking being continued as the oil gets exhausted and until the water becomes too troublesome, when it is found cheaper to open other shallow wells. In this way the wells are only from two to three fathoms apart. The Mikowka shaft is twenty-one fathoms deep; at six to seven fathoms it yielded about 4 cwt. of oil daily, but the quantity diminished as the shaft went deeper. There is no stratigraphical observation to account for this, but it may be presumed that the shaft passed into less oily beds. The Folinovka pit close by is also twenty-one fathoms deep, but yielded little oil, and further work was stopped by the influx of inflammable gases. The Ferdinand shaft at two fathoms got into grey shaly clay full of oil, but no flow took place till the water was reached, when the oil flowed freely. This occurred in several shafts, the oil increasing with the flow of water. In some places, for a square mile in extent, the whole ground seems saturated with oil; elsewhere gas and earth-wax (ozokerit) are the only signs of the oil, which probably exists at greater depths. Wells close to each other yield quite different quantities of oil, and that only for a certain time, when they have to be deepened. It is asked then, What would be the prospect of deep borings on the American system? Upon the supposition suggested by M. Foetterle, that the oil is produced near the surface, there would be none. But Dr. Hochstetter remarks that he found neither bituminous shales nor pyrites in any abundance; the beds in which the oil appears are sandy and earthy shales poor in "bituminous matter," occurring in a definite narrow zone with a constant strike; and he agrees with M. Foetterle as to the horizon of that zone; yet he goes on to say that he considers these rocks to have nothing to do with the oil otherwise than as vehicles; that the oil is not indigenous in these beds through which it reaches the surface, but is the product of the destructive distillation of organic matter at great depths, in coal-measures or other rocks that may be supposed to underlie the Carpathian sandstones. He indicates vaguely the difference of stratigraphical conditions here and in Pennsylvania where the oil-beds are struck at definite horizons, whereas in Galicia it is declared that the only chance of abundant oil is by tapping one of the more or less vertical deep-seated fissures through which it rises to be diffused in the crushed strata near the surface where it is now slowly extracted. Here, as in other fields, it is found that the lighter oil comes from the greater depth. Dr. Hochstetter's view seems like a hasty recoil from the superficial origin suggested by M. Foetterle, and a too ready extension of that assigned by M. Posepny (to whom he refers) for oil found in certain newer beds in East Galicia, connected with the great folding and fissuring to which all the strata have been subjected. He regrets that

[1] Jahrbuch d. k.k. Geol. Reichanstalt, Vol. XI (1865), p. 199.

no facts are available to test his views, for as yet (1865) no boring in East or West Galicia has exceeded 500 feet, while it would require numerous deep borings to arrive at any conclusion.

26. The oil-measures are much more productive in East Galicia, and an excellent sketch of them was given in 1865 by M. F. Prosepny.[1] He distinctly considers the oil to be indigenous in the bituminous shales with remains of fishes and the bituminous muds with fucoid remains occurring in the menilite group. In the later official geological map (1871) this group is distinguished as the *Amphysilen* zone, from the abundant remains of the small fish of that name; these rocks are also sometimes referred to as the fucoidal beds of the Carpathian series. M. Posepny considers that the evolution of the petroleum in these beds was encouraged by the great dislocations and crushing they have undergone giving access to decomposing agents (not mentioned): and the same fracturing has permitted the oil subsequently to find its way into contiguous older and newer rocks. The very abundant sources in the soft miocene sandstone at Borislaw are taken to be supplied in this way. The workings are described as of the most primitive and wasteful kind:[2] shallow pits (seldom over 20 fathoms) at a few feet apart, to the number of 5,000, new and old, within a small area. While in work a shaft yields from 5 to 80 cubic feet daily.

27. A much more exact study of the petroleum rocks of Galicia has more recently been given by Mr. C. M. Paul, of the Austrian Geological Survey.[3] His arrangement of the Carpathian rock-series would seem to involve considerable changes in the official map of 1871. The following groups are indicated:—

6. The neogene salt-marl (lower miocene).
5. The Magura and Kliwa sandstone.
4. The Menilitschiefer.
3. The eocene Carpathian sandstone.
2. The middle Carpathian sandstone.
1. The Ropiankaschiefer or lower Carpathian sandstone (neocomian).

Of these, Nos. 1, 3, 4 and 6 are oil-producing; but of course only in certain bands, which locally may be some metres in thickness. The oil mostly occurs in soft sandstone although no doubt originally derived from the associated shales abounding in organic remains. Mr. Paul has no doubt whatever that the oil was indigenous in these latter beds, any connection of oil-rock with faulting and fissuring of the strata being only incidental. Thus, in these rocks too the oil is not original in the beds in which it actually occurs most abundantly. Here again it has been observed that oil appears most frequently along anticlinal axes, but Mr. Paul very sensibly connects this with the better exposure of the beds in this position, and does not at all infer the absence of oil in the synclinal folds whenever they can be got at. Actually vertical strata offer the least favourable condition. His remark that in the few places where the oil-bearing rocks are little disturbed they have not proved productive, would perhaps need further elucidation; for if a general rule, it would certainly imply that the squeezing, with evolution of heat, elsewhere

[1] Jahrbuch d. k.k. Geol. Reichanstalt, Vol. XV, p. 351.
[2] M. Posepny's figured section is as primitive as the native mining he describes.
[3] Jahrbuch d. k. k. Geol. Reichsanstalt, Vol. XXXI (1881), pp. 131-168.

experienced had been an effective cause in the accumulation, if not in the production of the oil; the latter would be an instance of "pressure metamorphism," as compared with the regional metamorphism of the same kind appealed to by Mr. Carll. Under the foregoing conditions it is mentioned as obviously unwise, unless for purely experimental purposes, to put down a boring or well on the actual spot of a natural oil spring; the trial should be made at some distance, according to the amount and direction of the dip of the oil rock. I have reproduced in Plate II a number of figures from Mr. Paul's paper, they will serve to illustrate the structural conditions in such ground; they are diagrammatic (not to scale) and few particulars are given as to depths and yield. Of Mraznica (fig. 4) it is stated that pits 100 metres in depth had for ten years been yielding about 1,400 kilograms each weekly; while some had given ten times as much. Both figs. 4 and 6 represent isoclines,—flexures in which all the beds dip in the same direction; fig. 4 is on the up-curve side of the flexure, a folded anticlinal, in which the oldest beds appear in the axis of the denuded flexure; fig. 6 is on the down-curve side of the flexure, a folded synclinal, in which the newest beds are found at the axis of the denuded flexure. This latter is then an instance of productive measures in a synclinal; the Polana pits proved very productive. The Schodnica workings (fig. 9) are among the most prolific; the pits are about 160 metres deep.[1] For a time the Magdalen pit gave 80 cwts. per day, and became steady at 40 cwts. The Boryslaw mines (fig. 10) are in the newer rocks. They are the principal source of ozokerit. The area worked is about 1,950 metres long and 700 metres broad, in which some 12,000 pits have been sunk. Some 2,500 are now producing oil, and 935 are for earth-wax. The principal shafts are about 160 metres in depth. The production of earth-wax now is about 250,000 cwts. yearly. The output of oil used to be 200,000 cwts., but has fallen to 35,000 cwts.; the winning of the wax is so much more profitable.

## INDIA.

### *The Punjab.*

28. All the petroleum of India occurs in middle or lower tertiary rocks, as in Galicia and at Baku. Within or near the Rawalpindi district of the Punjab there are some 16 spots at which symptoms of petroleum occur. Some of these are very insignificant, the product being quoted in teaspoonsful; the best (at Gunda) yielded for six months an average of about 11 gallons a day from a boring only 75 feet deep. They are all described in Mr. Lyman's report. His attempt at a geological correlation of the rocks at these different localities is simply ridiculous; but that is of little practical importance for immediate purposes. His views upon petroleum itself are more serious: he seems to have practically held to the view that pretroleum is for ever confined to the bed in which its materials were deposited; a notion that is demonstrably erroneous for the greatest known oil sources; and to a very important extent so in other regions, as in Galicia. Upon an extra arbitrary exercise of this opinion he actually formulated

[1] From the term used,—"Grube"—I infer that the extraction is by pits, not bore-holes, especially as borings are sometimes mentioned; but no particulars are given.

a rule (*l. c.*, p. 8), that the limit of depth (in the bed) to be expected at any locality would be half the length of the outcrop along which any trace of petroleum could be found. It is likely that the indications given by Mr. Lyman for the exploration of these localities are affected by these peculiar views: that a rock in which an accidental exhibition of oil occurred may have been indicated in both directions as an oil bed. Still, the descriptions and the detailed plans in his report supply an excellent basis for further explorations, for he seems to have been a good surveyor. At first at least, exploration should be limited to the neighbourhood of these natural springs; if it should be proven that these are but a faint indication of oil-bearing rocks underground, it may be permissible to attempt places where no such indications occur. The fact that all these localities occur in about the same geological horizon strongly confirms the opinion that the oil lies in and about its original birth-place; see section fig. 3, pl. I; the oil occurs in the bands numbered 5 and 6.

*Khátan.*

29. The best local description of the oil-measures of this North-West region is that by Mr. R. A. Townsend in his account of the Khátan field in the Marí hills of Baluchistan, where he has recently carried out some successful borings in spite of most trying obstacles, both underground and above it. His report is printed herewith. The identifications of fossils and of geological horizons may not be quite correct, but we have seen that this is almost irrelevant to the question. Not so however the theoretical considerations regarding the origin of the oil, for the process of search must be largely influenced thereby. The notion of any essential connection between petroleum and the salts and sulphurous products that so often accompany it, is now very generally abandoned, the association being only incidental, or at most concomitant. There may be deep-seated coal beneath all this ground—Mr. Oldham's suggestion of Gondwana coal-measures in Rajputana, at the eastern edge of this geological region, would be a direct hint at such a possibility—but there is really no excuse for looking afar for what seems to be in our hand: Mr. Townsend's own description is the most satisfying yet on record that the oil is indigenous in these eocene rocks, probably in the shales that are described as so densely charged with organic remains, although the associated fractured limestones have afforded in their crevices convenient receptacles for the oil. I certainly think that this view should be the one adopted for immediate operations. Upon it, the Khátan boring would seem to be at the base of the measures, and may be already below them. A more likely site would be on outcrop No. 25 of the section, though not necessarily on this actual line, better at a lower level and where the dip is lowest so as to cut as many beds as possible. These shales are described as themselves oil-bearing. The 'marine conglomerate,' the chief oil rock of Mr. Townsend's report is, I am pretty sure, the 'limestone breccia' described by Mr. Blanford in his sketch report on that region[1] as occurring so widely at or near the base of the lower eocene series. Specimens of it sent by Mr. Townsend certainly contained nummulites; and Khátan is coloured as eocene on Mr. Blanford's sketch map, though he was not

able to visit that particular ground. I have found, in descriptions of works in similar measures elsewhere, notice of the great practical difficulty mentioned by Mr. Townsend of keeping a straight hole in rocks that are much broken or disturbed; the cutter must be reflected laterally on striking a hard surface obliquely, and so be diverted from the plumb line. I imagine that this difficulty has had much to say to the practice in Galicia of sinking deep pits instead of borings, notwithstanding the special advantages of the latter in the extraction of petroleum. But for the remark quoted above from Mr. Paul, that the measures in Galicia are not so productive where little disturbed, and for the independent uncertainty of their occurring anywhere on the same horizon, one might recommend a splendid place for a speculative trial boring at the base of the Kirthar limestone near Rohri on the Indus. It will be tried some day.

### *Assam.*

30. A brief notice of the petroleum springs in connection with the coal-fields in Upper Assam was published in 1865, in the Memoirs of the Survey, Vol. IV, Pt. 3, p. 29, with a recommendation that trial borings should be made. In 1866 a Calcutta firm obtained a license to explore the ground and commenced operations in November of that year. A short account of this enterprise was published in the Survey Records for 1874, Vol. VII, pt. 2, quoting also a distillation assay of the oil, as compared with that of Pennsylvania and Rangoon oils. The results of the Makum borings were all that could be desired: none of the holes were of considerable depth, apparently less than 200 feet, yet in some the oil spouted intermittently with a pressure of 30 lbs. to the inch, yielding as much as 3,500 gallons in 35 hours from a single pipe; the dimensions were not given. Notwithstanding this superabundant supply the enterprise broke down, owing to the difficulties of transport from so remote a site. A further notice of the Assam petroleum is given in Mr. Mallet's report on the Naga Hills coal-fields (Memoirs, Vol. XII, Pt. 2), with an enumeration of places where the oil appears naturally at the surface. An apparent connection of this petroleum with the coal occurring in its immediate vicinity is more marked than usual. Mr. Mallet mentions having in one instance seen oil oozing out of the coal itself. There is nothing, however, to confirm the idea of any real connection: this coal is still the most highly 'bituminous' coal in India. Thick soft sandstone is the prevailing rock, but blue clay is mentioned as occurring in the borings; all are much disturbed. The exact age of these rocks is uncertain; they are more likely middle than lower tertiary. There can scarcely be a doubt that the oil resources of this region are very great. At present most of the best ground is within the immense concession granted to the Assam Railways and Trading Company; but apparently the oil is neglected.[1]

### *Arakan.*

31. The coast of Arakan, from Cheduba island northwards, exhibits an immense thickness of tertiary rocks, chiefly sandstones and shales, crushed to-

[1] I recently had occasion to apply to the Manager at Dibrugarh for a barrel of oil, but was informed that the Company scarcely got enough for their own uses.

gether in more or less vertical folds. The same rocks and features continue northwards through Chittagong and the Tipperah and Lushai hills into Cachar. They are separated from a like accumulation of deposits in the basin of the Irawadi by the Arakan Yoma (range), continued northwards into Manipur, composed entirely of sedimentary rocks, the oldest of which seems to be of triassic age, with some considerable masses of serpentinous eruptive rocks. South of Cheduba the coast line is weathered back to the axial rocks, ending at Cape Negrais. The region of the islands and the adjoining coast has long been remarkable for its numerous mud volcanoes, caused as elsewhere by the eruption of hydrocarbon gases, and also as usual petroleum occurs freely in the neighbourhood and has for long been extracted by the natives, supplying an export of as much as 40,000 gallons a year from Kyoukpyu. The oil is very light and pure, and can be burned in lamps without refining. An excellent description of this ground by Mr. Mallet, was published in the Records for 1878, Vol. XI, Pt. 2, giving particulars of the mode of occurrence of the petroleum. In 1877 European enterprise was attracted to this industry and very promising results were at once obtained: one of the first wells, only 30 feet deep with a boring continued 36 feet deeper, gave a flow into the well, yielding at first about 250 gallons a day. In 1879 more extensive works were undertaken by the Borongo Oil Company. They started work most energetically, with a large staff of skilled workers of all kinds; they set up two stills of 4,500-gallon and 9,000-gallon capacity; in 1883 they had 24 wells in work ranging from 500 to over 1,200 feet in depth; for a few weeks one well yielded 1,000 gallons daily, but the total amount of crude oil pumped from 10 wells during the whole year did not exceed 234,300 gallons, of which they refined 65,450 gallons and sold the rest in a crude state. In 1884 the Company had to suspend payment. In the official report[1] from which these facts are taken there is a naïve remark that goes far to explain the whole calamity,—"As yet no one in the Kyoukpyu field has discovered oil-bearing strata of the type of the good American or of the Caspian field, and so far the business of oil-winning on a large scale has not been a success." No doubt the promoters of the enterprise, like the enthusiast alluded to in para. 21, reckoned on that sort of thing; it is the unfortunate mistake alluded to in para. 4, yet an intelligent diagnosis of the ground should have warned against such an expectation. There are no doubt very large supplies of high class petroleum to be got from this region, but it must be won by suitable methods. In Mr. Carll's work on the Pennsylvania oil-fields he bitterly laments the irretrievable loss of information through the want of intelligent record of such costly experiments: of the many thousand borings put down in that region, not one record in fifty, if obtainable at all, was trustworthy. We may echo the same regret here; no doubt useful hints for future guidance might have been obtained by intelligent observation of the numerous borings in Arakan.

*Burma.*

32. 'Rangoon oil,' under some other name, was probably an object of industry in pre-historic times. For many years it has been a steady article

[1] Administration of British Burma during 1883-84, p. 31.

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.

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

Roads.

The Road from Sibi to Khátan *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.



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

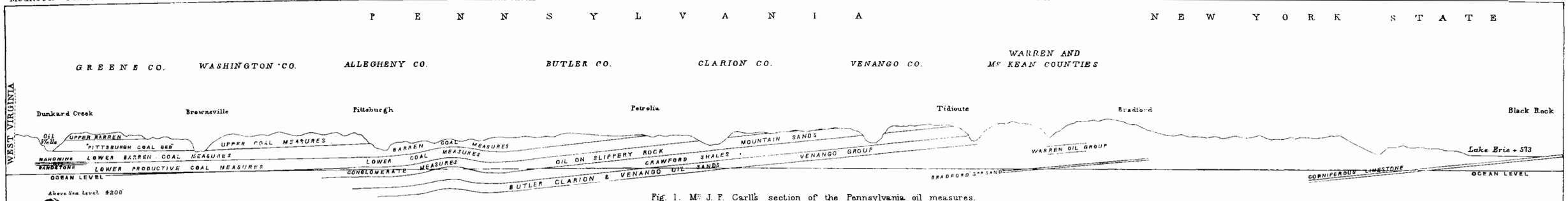


Fig. 1. Mr J. F. Carll's section of the Pennsylvania oil measures.

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

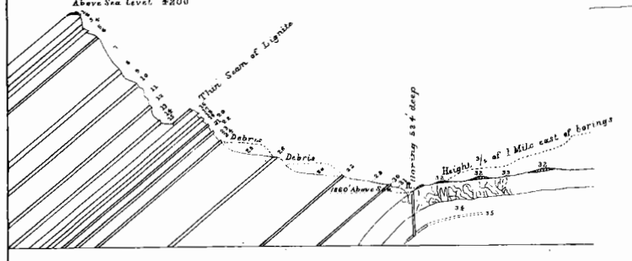


Fig 4. Mr R. D Townsend's section of the Khalan oil springs.

*Length 7200 feet Scale. 4" = 1 mile.*

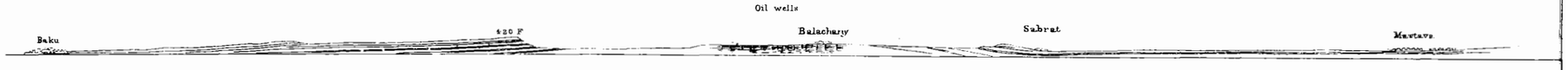


Fig. 2 Professor Abich's Section of the Baku oil measures.

*Length 16 miles. Scale 1" = 1 mile.*


Fig. 3. Mr A. B. Wynne's section of the Punjab oil region. Length 180 miles. Scale 1" = 5 miles.

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

On Stone by Aminullah

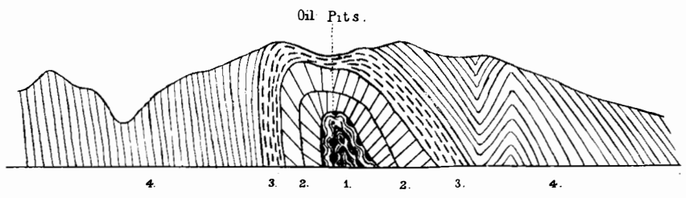


Fig. 1. Rozpucie.

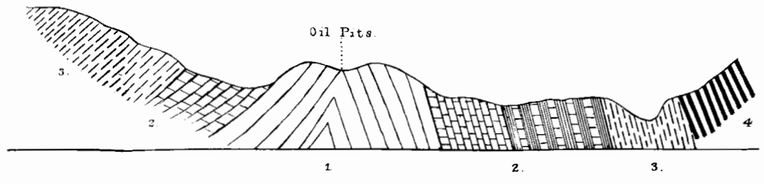


Fig. 2. Rosochy.

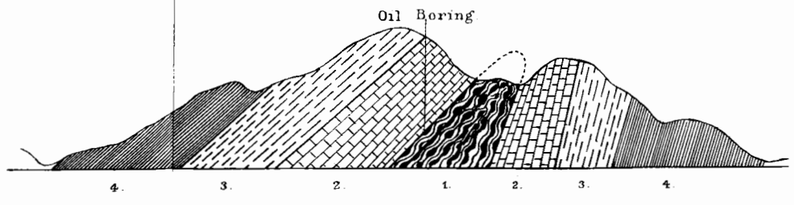


Fig. 3. Kreciata.

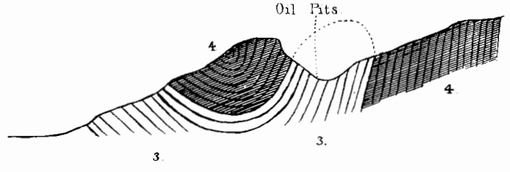


Fig 8. Holowiecko.

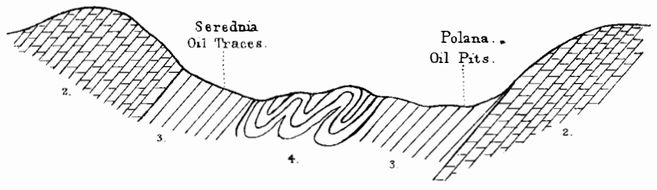


Fig. 6.

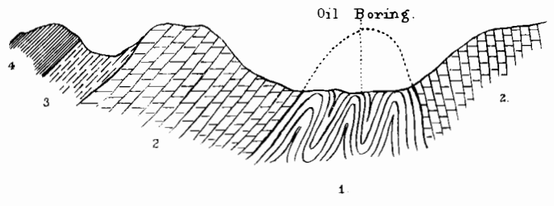


Fig. 5. Orow.

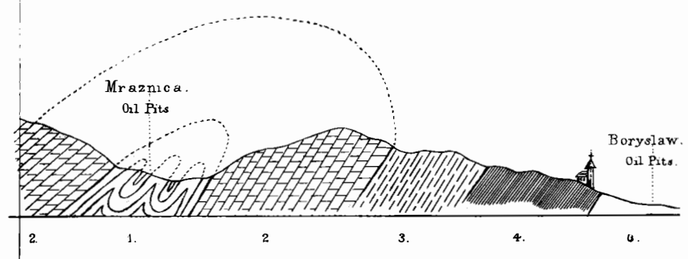


Fig. 4. Mraźnica.

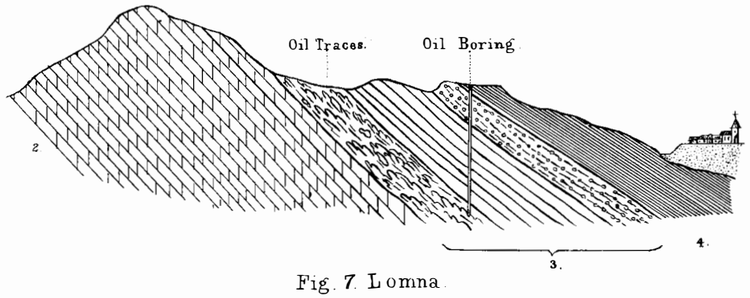


Fig. 7. Lomna.

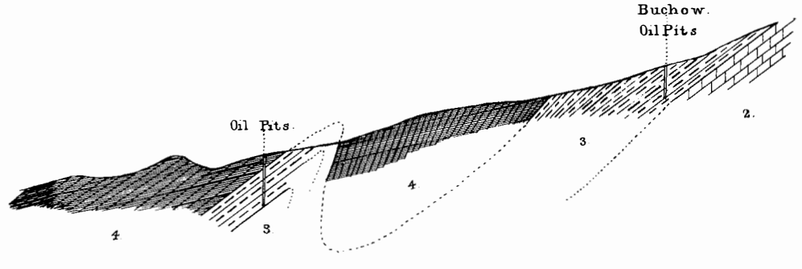


Fig. 9. Schodnica.

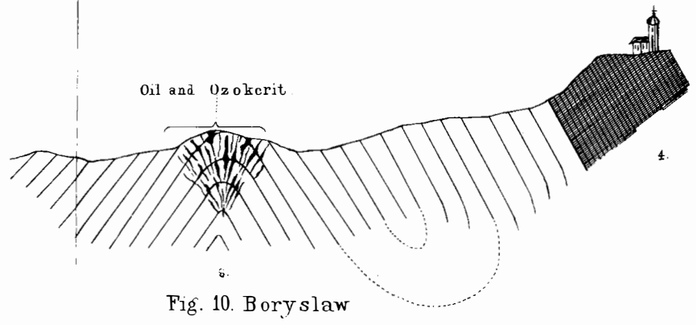


Fig. 10. Boryslaw

LOCAL SECTIONS OF PETROLEUM MEASURES IN GALICIA, BY Mr C. M. PAUL: (Copied from the Jahrbuch d.k.k. geologischen Reichsanstalt, Vol: XXXI. 1881.)

On Stone by S. K. Hossain.