

THE FORMATION OF ASPHALT VEINS.

GEORGE HOMANS ELDRIDGE.

INTRODUCTION.

Asphalt veins as they occur in the superficial strata of the earth's crust afford a study in black and white of many features of ore deposition in general. Such veins are not only easy to follow when they are once opened, but they are often clearly marked across the country, especially where the surface is formed by a resistant rock rather than by one readily disintegrating into soil. It is possible indeed in certain instances to follow the outcrop of a vein for several miles by simply occupying some prominent point along its course and turning the eye in either direction.

Not only is the study one of simplicity, due to a sharp contrast of the black asphalt with the lighter colors of the adjacent rocks, but even in the character of soils and verdure the course of the vein is marked, either by a complete absence of plant growth or a change in the character of the vegetation. While these elements of contrast are to be observed in most occurrences of asphalt veins they may be studied under exceptionally favorable conditions in the enormous gilsonite veins of Utah.

OCCURRENCE OF ASPHALT VEINS.

Distribution.—As actually observed by the writer, asphalt veins occur in many parts of the United States, both east and west, in Cuba and in many other parts of the West Indies. By reference to literature on the subject it is evident that they are scattered through most of the explored territory of the earth and that they are of far wider distribution than veins of metalliferous materials. This is doubtless due to the limitation of metalliferous veins to the proximity of deep-seated mineral-bearing waters which have found a passage either through the older, crystalline rocks, or through such of the later sedimentaries as have been violently folded or otherwise rendered pervious. The wider

occurrence of asphalt veins is due also to the fact that petroleum, the mineral from which the asphalt has been derived, has an extensive distribution in the stratified rocks from the oldest to the youngest. In the crumpling to which the crust of the earth has been subjected such strata have frequently been folded and then exposed by erosion.

It will be found in the study of what follows that there is no marked difference in vein phenomena, whether the fissures be filled with bituminous matter or metalliferous ores and gangue, either from point to point on the veins, or from formation to formation which they traverse. The character of an asphalt vein depends largely on the nature of the country rock and this is also the case in deposits of metallic ores.

Nature and Origin of the Fissures.—The purer varieties of asphalt occur in fissures, and it is to these that the present discussion is confined. The formation of all fissures in the rocks of the earth's crust has been brought about by one or the other of two causes—folding or contraction. When fractures are due to folding a displacement of the originally adjacent walls has often taken place while in the fissures produced by contraction this does not necessarily occur.

To assign the origin of a fissure to the latter cause is, however, often attended with considerable uncertainty, because lack of displacement may accompany phenomena of the first class. The greatest asphalt-filled fissure in the world is one in which there is no displacement, the vein having a maximum width of eighteen feet and a length of no less than ten measured miles. Others occurring nearby are only a little smaller and in addition display the phenomenon of forking. In both instances the veins trend in the direction of the dip of the enclosing strata. They are, therefore, more probably the result of contraction than of folding, the axes of the flexures trending at right angles to the veins.

To what such contractions of the strata are due it is impossible to say, and it is also impossible to ascertain the causes which have determined the directions assumed by the fissures. Contraction is supposedly the result of loss of heat or of moisture, the latter having taken place during the drying out of the beds. The for-

mation of such fractures must have occurred while the strata were deeply buried beneath overlying measures, and it may be that as originally formed they were characterized by little or no displacement. If so they are comparable to minute rifts that occur in new excavations of the present day. In a measure this might account for the many instances in asphalt veins in which there has been no displacement of the adjacent walls. This is perhaps not such a remarkable occurrence when the depth at which the fractures occurred is considered and when the extent of the cracks is brought into direct comparison with the vastness of the measures which they have affected.

Dimensions of Veins and their Relation to the Enclosing Rocks. The lineal extent of asphalt-filled fissures varies from a few feet to many miles. In width the fissures, when single and uninterrupted by horses or inclusions that have fallen in from the walls, range from a maximum of eighteen feet down to extremely fine, thread-like crevices whose length is always disproportionately great. A clean fissure frequently attains a width of several feet.

In most cases instead of a simple fissure a zone of fissures has been formed in which a large number of separate fractures occur, the smaller ones interlacing with one another and the whole network together affording a large aggregate space for the passage of the material with which the fissure is filled.

This latter mode of occurrence is the more interesting as it affords a close parallel to characters more commonly found among veins which carry metallic minerals, particularly those in areas of crystalline schists or in the sedimentary slates of more recent geologic epochs. Simple ore-filled fissures on the other hand are usually confined to heavy-bedded rocks such as limestone and sandstone or to massive granitic rocks.

Among asphalt veins are found some remarkable examples of tenuity. In the region where the wonderful veins of Utah are found the writer has observed one instance of an uninterrupted asphalt-filled fissure of a width not exceeding one half an inch and a lineal extent of fully four hundred feet. It appears at the surface as a jet black line and when viewed from a distance resem-

bles a carbon crayon mark drawn on the eroded surface of light colored yellowish gray sandstone.

The downward extent of the fissures is more difficult to determine and must, in the absence of deep workings, remain uncertain. In general, however, the vertical range of the more persistent veins of clear material is greatest in massive beds of sandstone, indeed it is practically coextensive with the thickness of the enclosing rocks. It is thought that the great Cow Boy vein in eastern Utah had, before erosion affected the strata, a vertical range of at least 2,000 feet, which is the thickness of the massive sandstone in which it occurs.

In addition to the long straight veins another type may often be noted in which the veins show a closer relation to the folded structure of the enclosing rocks and exhibit a higher degree of complexity.

An excellent illustration of this type may be seen in one of the asphalt districts of Cuba. The veins are located on the nose or easterly end of an anticline. On the sides or limbs of the fold at some little distance from its downward pitching extremity are one or two normal strike fissures. As one approaches the end of the fold the rocks become relatively broken and crushed and the regularity of the strike fissures is lost in the complexity of the interlocking fractures. The general trend of the zone of fracturing, however, continues as a whole to follow the strike of the beds, curving around the pitching end of the fold and connecting the strike fissures on the one limb with those on the other.

The strata in this case comprise a succession of thin-bedded limestones and calcareous clays. The limestones predominate but the clays are in sufficient abundance to give to the measures a thinly laminated character, rendering them, in a sense, transitional between a typical heavy-bedded and a typical shaly series. The veins, therefore, are likewise transitional, neither as regular as those usually found in heavy-bedded rocks nor as irregular as those in shales.

Relation of the Veins to the Enclosing Strata.—The character and value of the veins are dependent on the type of rocks in which they occur. Those which are found in the more heavy-

bedded rocks are the more regular, those in thinly laminated shales are often extremely irregular. When a vein passes from a heavy-bedded rock above or below into shales, it generally splits into a number of fissures of smaller dimensions. These then follow divergent directions ramifying through the shales in an intricate manner, and are, with few exceptions, without value. Occasionally great bodies of asphalt are to be found in clay or shale beds, but they are in the nature of pockets. These pockets may occur singly, or several may lie along a single crack or zone of fissuring, connected through the intervening spaces by minutely ramifying fissures almost void of bitumen. Many of them have been mined in the western part of the United States, but have in all cases, sooner or later, proved unprofitable, and have been abandoned. The regular fissures in the massive sandstones have so far been the only deposits of commercial value.

COMPARISON WITH METALLIFEROUS VEINS.

Horses.—Veins of asphalt show the same peculiarities of structure as those of the precious metals, but on account of the contrasted colors of the vein matter and wall rock these may be much more readily observed. This is particularly true in the case of included fragments of country rock, for in a vein of asphalt there is never any difficulty in recognizing horses of rock that have fallen in from the walls. Indeed it is often possible to determine the precise position which they originally held upon the wall, as the distance through which they have traveled is often less than three feet. At other times a body of rock hangs by the merest thread to the wall on the one side or the other of the fissure. The size of the horses that have been observed by the writer varies from a few inches to five or six feet in width and in length from three or four to twenty or thirty feet.

Movement along Fissures.—The walls of the fissures frequently show slickensides indicating a movement in the direction of the markings. This usually coincides with the direction of the vein but the amount of movement seems generally to have been small as it is often difficult to detect any relative displacement of the rocks on the opposite sides of the fissure. Another evidence of movement is the variation in width which the veins sometimes

exhibit. In most cases, it is true, they are comparatively regular but pinches and swells forming bonanza-like pockets occasionally occur. These are connected with one another by constricted portions of the vein which contain little bituminous material. Such variations are usually explained in metalliferous veins by displacement. The fissure having had an undulating course in its downward extension the subsequent movement has brought the concave and convex portions opposite to one another, forming a constriction between two convex and a widening between two concave portions.

The presence of shoots following diagonal downward courses in the vein, a feature so often observed in metalliferous veins, has not yet been detected as exploitation has not been sufficiently extensive to reveal them.

THE GENESIS OF ASPHALT VEINS.

The genesis of asphalt veins involves much uncertainty. The question is readily divided into two distinct phases: (1) origin of the material which fills the fissures; (2) the immediate source from which the asphalt has been derived and the manner in which it was introduced into the fissure.

Origin of Material.—There is little question at the present time that the asphalt has been in some manner derived from petroleum, although the exact process by which this has taken place is not yet clearly understood. Among the evidences which prove that petroleum is the source of the asphalt none is clearer than that afforded by the remarkable parallelism of asphaltic and petroleum products. Thus there are amongst the oils a dozen different types: naphthas, illuminating oils, lubricating oils, and natural residual oils, each of these exhibiting several varieties of composition. In the same way among the asphalts there are grahamite, albertite, gilsonite, wurtzelite, ozocerite, negrite, and the simple variety of the hardened oil which passes under the name of asphalt. The chemical and physical properties of these series show a close correspondence which may even be extended to the minor subdivisions of the several groups. It is, therefore, not so remarkable that with the different types of oils as an original source there should be a corresponding series of asphaltic products

derived from them. In some cases the evidences of such derivation are of a geological character and are susceptible of actual observation. A bed of paraffine has recently been found in Alaska on the western shore of Cook Inlet presumably associated with a fissure and from the manner of its association has unquestionably resulted from an outpouring of a light illuminating oil of paraffine base.

While the similarity between oils and asphalts thus affords us practically conclusive evidence as to the derivation of the latter from the former, it does not afford a clue as to the ultimate origin of the petroleum itself.

Manner of the Filling of the Vein.—It seems highly improbable that the petroleum or asphalt was formed as such in the fissure. Indeed the manner of its occurrence serves to disprove such a supposition. It is much more probable that it was introduced into the fissure from original deposits in the neighboring strata or from rock reservoirs in which it had been previously accumulated. A study of the rocks associated with these veins will serve to throw some light upon this question. These are in all cases sediments; either sandstones, shales, clays or limestones, or alternating beds of one or all of them. While the sandstone rarely shows impregnations of asphalt the limestones, shales and particularly the clays do show such impregnations. The limestones and shales are also more or less richly impregnated with bitumen. The first impression which one receives when considering these facts is that the asphaltic material which fills the veins has been derived from this disseminated bitumen. It has not thus far been observed, however, that the shales or limestones adjacent to the veins have been deprived of any portion of their bituminous contents. The explanation of this phenomenon may be that in the passage of the petroleum from the shales into the fissure, the material first having its exit into the cavity has been followed by other material behind and so on, until the operation has been brought to a close by the complete filling of the opening. The fissure and the adjacent strata are thus left filled with bitumen, and only that territory which is somewhat remote has been drained. Under the most favorable circum-

stances it would be a difficult matter to determine whether such remote territory had suffered a loss of its original content or had not at any time contained appreciable amounts of bitumen. The occurrence of oil well phenomena of the present day affords some confirmation of this theory of the flow of petroleum to a fissure, as the adjacent strata are exhausted. The oil wells which are large producers may be considered as taking the place of the natural fissures, inasmuch as such fissures would tend to exhaust the supply in much the same way as the series of productive wells. The oil in a productive region flows from the adjacent strata into the wells and from the more remote strata into the adjacent strata, until the entire pool has been depleted. If the flow be checked prior to complete exhaustion, the well and the adjacent strata are left full rather than the strata which are more remote. We should, therefore, expect the same sequence of events to take place during the formation of asphaltic veins.

Without entering into the difficult question of the flow of liquids at great depths below the surface, it seems well to venture upon a suggestion as to the manner in which the oil has been moved from its original position into the vein. The asphalt veins may have been formed either with or without an opening to the surface. In most cases it is presumed that no connection with the surface existed. In such a case a vacuum would probably have been formed here when the fissure was opened and a powerful suction exerted upon the disseminated bitumen in the surrounding rock. It is probable also that the flow of material to the fissure has been aided by an expansion of the gases associated with the oil, such expansion occurring at the moment when the formation of the fissure relieved the pressure. The hydrostatic pressure of a salt water column as shown by Orton may further have operated in a similar manner to accelerate the introduction of material into the fissure.

In those cases where the asphalt-filled fissures actually extended to the surface (and the evidence of such an extension may often be seen in the presence of an overflowing breccia deposit) the expansive force of compressed gases and the weight of the hydrostatic column must have been sufficient to overcome the resistance of the air in the cavity.