INTRAFORMATIONAL SOLUTION OF THE FLOYDS KNOB LIMESTONE

Paris B. Stockdale, Ohio State University

Introduction. Further significance of intraformational dissolving of rocks has been revealed from numerous observations made incidental to the study of the stratigraphy of the Floyds Knob formation of the Borden (Knobstone) group of southern Indiana. Previous studies of the writer[1] have already developed various stratigraphic peculiarities, in limestones particularly, which cannot be ascribed to events at the time of the birth of the rock but which are explained by partial dissolving of the rock subsequent to the deposition and consolidation of the sediments. The *complete* removal in places of the soluble constituents throughout the entire thickness of the limestone facies, with a bed of reddish-brown claylike residuum offering the only testimony to the original existence of the limestone layer, is the unique feature of the Floyds Knob formation which provokes the offering of this paper.

Floyds Knob Formation. Extensive field study of the Borden rocks throughout the unglaciated area of southern Indiana, and incidental observation in adjacent parts of Kentucky, revealed a persistent unit in the upper part of the Borden group which has served as a vital key to subdividing the rocks and to properly associating the uppermost Borden formations with the overlying Harrodsburg and Salem limestones. The name Floyds Knob formation is being suggested for this unit[2]. This formation is one exhibiting several lithologic facies, the most common of which is a limestone that is itself of differing traits from place to place. For this limestone phase the name Goss Mill limestone facies is being suggested.

The thickness of the Floyds Knob formation, the Goss Mill facies, is commonly 3 to 4 feet. In but a few places it is as much as 8 feet or more. The facies crops out in southeast Harrison County; south, east-central, and northeast Floyd County; parts of extreme west Clark County; southwest Scott County; southeast, north, and northwest Washington County; southeast, east and a limited part of northeast Lawrence County; southwest, west-central and northwest Jackson County.

In some places the Goss Mill facies is a ferruginous, siliceous, brittle limestone, carrying a deep-brown color at weathered exposures. The following analysis of a sample from the exposure along State Highway No. 62, at the northwest corner sec. 6, T. 3 S., R. 6 E., about one-fourth of a mile northeast of the village of Edwardsville, illustrates the composition:

---

[1]Stockdale, Paris B., Stylolites: their nature and origin: Indiana Univ. Studies, Vol. 9; No. 55 1-97, 1922; The stratigraphic significance of solution in rocks: Jour. Geology, Vol. 34, 399-414, 1926.
[2]Complete results of the writer's stratigraphic studies of the Borden group have been prepared in a report for publication by the Indiana Department of Conservation, Division of Geology. In this, the stratigraphic subdivision of the Borden rocks and appropriate names for the several stratigraphic units and their facies are being proposed.

	Per cent
Silica (SiO_2)	42.80
Alumina (Al_2O_3)	1.80
Ferric oxide (Fe_2O_3)	6.40
Calcium carbonate ($CaCO_3$)	46.70
Magnesium carbonate ($MgCO_3$)	2.05
Total	99.75[3]

A much higher magnesian content is indicated by the following analysis of a sample from near the top of the quarry of the Lehigh Portland Cement Company, SE. ¼ NE. ¼ sec. 18, T. 4 N., R. 3 E., one mile east of Sparksville:

	Per cent
Silica (SiO_2)	18.84
Alumina (Al_2O_3)	3.99
Ferric oxide (Fe_2O_3)	9.25
Calcium carbonate ($CaCO_3$)	43.65
Magnesium carbonate ($MgCO_3$)	22.79
Total	98.52[4]

At numerous places the formation is a fairly pure limestone, being crinoidal, oolitic or crystalline, or most commonly a combination. The color of such a limestone where fresh ranges from light to dark gray. Numerous small brown specks are common to the stone. Vertical and lateral transitions from the more pure to the impure, ferruginous, siliceous stone are frequent. North of Lawrence County the Floyds Knob formation is of a facies characterized by little limestone but dominated by a peculiar, brittle, yellowish siliceous rock, only slightly calcareous.

Various Indiana workers have referred to the different limestone facies of the Floyds Knob formation as the "Stevens Creek Limestone", although the name has never been formally proposed in the literature. Preëmption of the term for the "Stevens Creek slates"[5] of south Carolina, and confusion in the interpretation of different beds which have been referred to the same horizon in the northern part of the unglaciated outcrop area, preclude continuation of the name "Stevens Creek." The foregoing description of the Floyds Knob formation is intentionally a meager one. Complete discussion of the formation and its many complex problems and confusing stratigraphic associations are given lenghty treatment in the previously mentioned report which deals with the stratigraphy of the entire Borden group.

REVIEW OF THE INTRAFORMATIONAL SOLUTION PROCESS

The strongly supported fact that solution by ground waters within a rock mass is the vital factor in the development of stylolites, brought to the writer's attention the question of how significant has been *intraformational solution* in

[3]Analysis by Paul Smith.
[4]Furnished by W. H. Weitknecht.
[5]Sloan, Earl, Catalogue of mineral localities: South Carolina Geol. Survey, 1908.

producing other effects which require consideration in the interpretation of geologic sections and in the making of historical deductions. Before treating the observations in the Floyds Knob formation, Goss Mill limestone facies, which have further bearing on the subject, pertinent points relevant to the nature o- intraformational solution will be reviewed.

Significance of Stylolites. Stylolites present a peculiar and unique phenomenon which has been observed by all. Their manner of origin is relatively simple. Chemical and field investigations have strongly confirmed the idea that stylolitic phenomena are developed in certain types of rocks by *differential* chemical solution of the *hardened* strata, rather than developed in the soft unconsolidated sediments at the time of, or shortly following deposition, by some peculiar differential compression[6]. Stylolites, thus, are one case of a secondary stratigraphic feature, produced by a secondary process—solution—in the already hardened strata. Inasmuch as comparatively little attention has been given to this type of solution work, certain geologic significances of it have been largely overlooked. In addition to having produced, under proper conditions, the peculiar stylolitic and related phenomena in rocks, the stratigraphic importance of the solution is primarily twofold:

1. A part of the original rock has been removed and the beds consequently have been made thinner. Thus the apparently complete record of sedimentation is not represented in a given bed, and various peculiar relationships may have resulted.

2. Thin claylike films or partings have been developed within and between the beds as a residual product of the dissolved rock. Such partings are not original sedimentary layers, but have been introduced into the rocks as partings subsequent to the deposition of the sediment, and require a unique interpretation.

Prominent solution is restricted to carbonate rocks—principally to limestones, dolomites, and marbles. Stylolites are, with rare exceptions, limited to such types of rocks. They are not to be found in clastic rocks (except, perhaps, in occasional horizons where a high carbonate content is present), in igneous rocks, nor in most types of metamorphic rocks. Although solution is slightly effective upon materials which are nearly insoluble, such as quartz—especially when long periods of time such as geology offers are available—the effect is little as compared with that in the much less resistant rocks. The frequency of stylolites in limestones and marbles is, of course, well known.

Stylolitic phenomena result from a *differential solution* of the consolidated rock, under some pressure, on the two sides of a parting, such as a bedding plane, the undissolved portions of the rock on the one side fitting into the dissolved parts opposite, the interfitting taking place slowly and gradually as solution continues. A normal claylike substance is left as a residue from the dissolved rock. Most of this residue rests as a cap at the ends of the stylolites. The sides of the columns are fluted, striated, and even slickensided as a result of the slow movement involved.

Essential factors in the development of stylolites may be summarized as follows: (1) A first requisite is a rock which is differentially soluble. Most commonly limestones, dolomites, and even marbles are not uniformly resistant throughout. Evidence of differential resistance to solution of such rocks is strikingly presented in honeycombed weathering effects. (2) Ground waters,

[6]Stockdale, Paris B. *Ibid.*

charged with carbon dioxide, must be present to act as the dissolving agent in producing stylolites. (3) Some sort of parting, along which water circulation is free and concentrated, is needed. This parting is most commonly a bedding plane, though it may be a crevice running in any direction—even a fault. It may be an unconformity. No original clay layer is necessary along the parting. (4) Pressure is needed to make stylolites. It may be static, resulting from the weight of the overlying rocks, or it may be lateral dynamic pressure. The amount of pressure need not be great. (5) Sufficient amount of time must be allowed. Since variations of the foregoing factors occur, solution produces effects with a great many differences.

No attempt will be made here to discuss the variations in the types of stylolites nor to review the abundance of evidence substantiating the theory that stylolitic features originate in hardened rock by solution and removal of material, instead of in soft plastic sediment by differential compression before consolidation. The prevalence of stylolites, originating in such a manner, indicates that solution is important in the modification of strata.

Reduction in Thickness of the Strata. Inasmuch as solution work of the type involved in the origin of stylolites leaves no cavities, the strata are necessarily reduced in volume in proportion to the amount of material that has been dissolved and carried away. That rock material has been actually removed from beds and that a part of the record of sedimentation has thus been lost, and that a new type of rock material, a residuum, has been introduced into the beds are significant factors commonly overlooked by geologists. Such changes are strikingly true in the case of the Floyds Knob limestone. Calculations have shown an approximate minimum loss from intraformational dissolving of as much as 35 per cent in some of the highly stylolitic beds of Tennessee marble (Holston formation). This figure is based upon the composite length of stylolites in the numerous stylolite-seams, compared with the total thickness of the beds. Where dissolving has not been differential, stylolites are absent, and a solution parting of fair regularity with its film or bed of residuum offers testimony of rock removal. Excessive dissolving along a restricted line initiates a cavern.

Intraformational Residuum. No limestone, dolomite, or marble is composed of 100 per cent carbonates capable of being removed through the action of waters charged with carbon dioxide. Decomposition of such rocks by solutions leaves a claylike residue consisting of the less soluble constituents most of which are nothing more than the clastic silts which had drifted out into the limestone making waters. The amount of residue which accumulates is dependent upon two main factors; namely, (a) the proportion of insoluble constituents in the original rock, and (b) the amount of rock which has been decomposed. The nature of such weathering is well known and will not be reviewed here. It has been common practice to interpret all types of thin claylike partings in limestones, dolomites, and marbles as signifying simply a temporary change in conditions of sedimentation from those requisite for limestone-making to those necessary for clastic silt accumulation. This erroneous view has often been accepted in connection with the caps of stylolites, in which case an original, continuous silt layer is considered as having been broken by the interpenetration of the columns.

The solution residue is not a true clay, or kaolin, for the chemical alterations necessary to convert a clastic silt sediment to kaolin are not completed in the initial decomposition of limestone. This would be especially true where the solution is within the beds and the minerals are not freely exposed to atmospheric gases. The residue is merely a concentration, with little chemical alteration, of the clastic fragments scattered throughout the limestone. Thus, chemically, such residual "clays" vary little from the expected composition of an ordinary shale. They may be very sandy. Such residual partings, however, lack the lamination produced by the sorting action of open waters.

SOLUTION EFFECTS IN THE FLOYDS KNOB LIMESTONE

The following are the important effects which dissolving has produced or helped to produce in the limestone phases of the Floyds Knob formation: (a) the outcrop where long exposed to weathering has become an incoherent, reddish-brown sandy clay; (b) there has been a meager development of stylolites; (c) small caverns, partly or completely filled with reddish-brown residuum, have been made at numerous places; (d) a total, or nearly total removal of the limestone, with a bed of residuum left in its stead, has resulted in some places; (e) minature faulting of overlying sandstone beds has been produced as a consequence of settling necessitated by removal of the limestone beneath.

At many outcrops, particularly of the more impure limestone facies of the Floyds Knob formation, aerial and sub-aerial dissolving, accompanied by other processes of weathering, have converted the limestone into rock ranging from but slightly modified, fairly resistant stone with a reddish-brown weathered surface, to a soft, incoherent, sandy reddish to yellowish-brown residuum. Quarrying back from the exposure has revealed the fresh rock. Where a high degree of decomposition of the stone has taken place at the outcrop one can readily overlook the presence of the formation, particularly if the overlying and underlying siltstones are badly disintegrated. Such situations have caused field workers to miss the formation at places where it is present and where knowledge of its existence would serve as a valuable factor in making stratigraphic and structural computations. This type of weathering is, however, of less concern in this treatment than that which has gone on underground, probably beneath the water table, and has not been governed by aerial exposure.

Stylolites are rare, though present in a few places where the rock is fairly pure. The Floyds Knob formation is a thin one and is commonly a single bed which does not offer a satisfactory parting within the zone along which dissolving would occur on opposite sides both above and below. Nevertheless, the existence of stylolite-seams in some of the bedded zones, as at the type section along U. S. Highway No. 150, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, gives testimony of the previously described type of differential intraformational dissolving.

The many small caverns which exist are unusual in a formation as thin as the Floyds Knob. (See Figs. 1 and 2.) The presence of an underlying tight formation of siltstone which offers resistance to the downward percolation of waters gives occasion for lateral circulation of ground waters at the horizon of the limestone facies of the formation. Springs and seepage are an expression of the situation. At some places the formation is so very cavernous that a greater portion of the stone is missing, and only remaining pillars serve as support for the overlying strata. The caverns contain large quantities of the residuum. Examination of the foregoing analysis of the limestone reveals high proportions of insoluble constituents which would be left as a concentrate from decomposition of the formation.

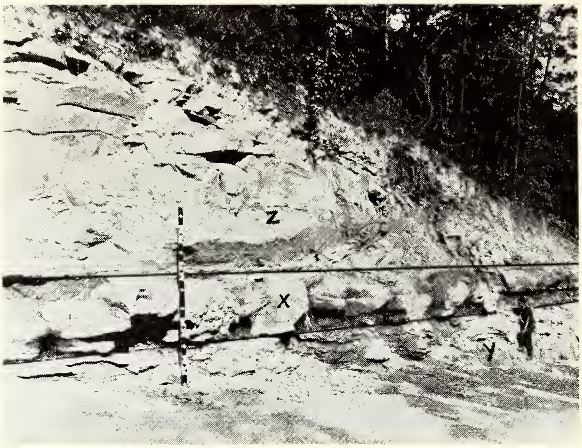

Fig. 1—Exposure along State Highway No. 62, near the northwest corner sec. 6, T. 3 S., R. 6 E., a short distance northeast of the village of Edwardsville. The Floyds Knob formation (X) here is 4 feet thick, consisting of a lower 2-foot zone of variable limestone, transitional with an overlying 2-foot bed of calcareous sandstone. The small caverns, partially filled with residuum, are testimony of the dissolving of the limestone. At the extreme right (man's hand) no limestone exists; in its stead there is a one-foot layer of reddish-brown residual clay.

Fig. 2—Exposure on the north side of U. S. Highway No. 150, at the top of Floyds Knob hill, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, showing the effects of intraformational solution in the Floyds Knob limestone. At the left end of the exposure there is no limestone; in its stead is a 3-foot layer of reddish-brown residuum (R). The overlying sandstone bed (Z) has been faulted down (at man's hand) due to total removal of the limestone beneath. To the right of this photograph the limestone is 5 feet thick. A cavern is hown at C. The man is standing upon a remnant of the limestone at the base of the formation.

Complete Destruction of the Limestone. In the making of stylolites no open cavities are left in the rock and the beds on opposite sides of the "solution parting" are uniquely interdovetailed as differential dissolving takes place. Partial loss of the rock and a reduction of thickness result. However, if widespread dissolving goes on more or less evenly in a bed on one side of a parting, or is shared by the layers on both sides, a stylolite-seam would not be produced. Thinning of the rock would be evidenced only the existence of the layer of residuum. Caverns, of course, are initiated through dissolving along restricted lines.

In the Floyds Knob formation there are places where the limestone throughout its entire thickness has been leached of its soluble carbonates. In the place of the limestone there is left a residual bed. (See Fig. 1.) It is this residuum that has been misinterpreted by some field observers. Relation of this layer of residuum to the previously existing limestone must be appreciated by workers in the area, otherwise a valuable key to the study of the straitgraphy and structure is overlooked. To interpret this bed as a clastic deposit signifying merely a temporary change in conditions of sedimentation, as a peculiar facies of rock whose lateral associations are unimportant, is fallacious. Prior to recent excavations a one-foot outcrop of reddish-brown clay was the feature of a significant section along State Highway No. 62, at the northwest corner sec. 6, T. 3 S., R. 6 E., about one-fourth of a mile northeast of the village of Edwardsville. In this "clay" are corroded chunks of the Floyds Knob limestone. The relation of this residual layer to the limestone was unappreciated by Butts, for example, who simply gave in his Edwardsville section one foot of "red clay"[7]. Butts listed the 2 feet of stout siltstone which overlies the "red clay" as the topmost bed of the "Holtsclaw sandstone". In the Kentucky sections a thin "layer of oolite", present at places, had been regarded as marking the top of the "Holtsclaw sandstone" and as occupying a position at the "base of the Warsaw". This thin "layer of oolite" is the Floyds Knob limestone. Since at Edwardsville the limestone was missing in the section, but in its stead there was the unappreciated red claylike residuum, proper correlation and interpretation were overlooked.

Recent quarrying incident to widening of the highway has revealed much more of the Floyds Knob formation at the above discussed location near Edwardsville. (See Fig. 1.) Unaltered and cavernous limestone has been brought to view. The limestone layer is as much as 26 inches thick, the upper part being quite impure, siliceous, and transtitional into a stout calcareous layer of sandstone. At the end of the exposure where the limestone has been decomposed, the claylike layer has a thickness of some 10 inches. This at first appears to be an excessive quantity of residuum from so thin a limestone bed, but examination of the foregoing analysis of the limestone will reveal adequate insoluble constituents.

There are numerous other locations at which the Floyds Knob formation on first observation might be declared "missing", but careful examination will reveal a bed of residuum offering definite testimony to the horizon of the formation. Again, it is to be admitted that at a few places no positive evidence of the formation's existence is available. Along the road leading north from the top of Mitchell Hill, Jefferson County, Kentucky, there is a 12-foot exposure of massive, oolitic, crinoidal limestone, the Floyds Knob. Less than one-fourth of a mile away, along the road leading south from the top of Mitchell Hill, the limestone is absent. At its horizon, however, is one foot of greenish (glaucontic) clay, overlain by a thin zone of reddish-brown residuum. The inference is that originally a limestone representative was there present, although it was not necessarily nearly as thick as the exposure a short distance to the north. Numerous other similar examples could be cited.

---

[7]Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pl. 53, opp. p. 158, 1915: Description and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, pl. 6, opp. p. 28, 1918.

Faulting. One of the singular effects of the removal through intraformational dissolving of the Floyds Knob limestone has been faulting of the overlying sandstone beds at a few places. Recent excavations along the north side of U. S. Highway No. 150, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, have revealed the situation illustrated in Fig. 2. The original limestone bed was 5 feet thick. At the west end of the exposure there is no limestone at the outcrop, but instead there is a 2 to 3-foot bed of reddish claylike residuum. The 2-foot basal sandstone bed of the overlying Edwardsville formation has been faulted down into the clay bed where the original limestone support has been removed. The throw of this small fault is 2 feet.

Conclusion. The significant effect of intraformational dissolving in the limestone facies of the Floyds Knob formation of southern Indiana has been the total removal at numerous places of the soluble constituents of the rock, with a bed of residual material left in its place as an indicator of the horizon of the formation. Such residual beds have been falsely interpreted in the past as layers of clastic sediment, and as a consequence their horizon has been misinterpreted and their association with the Floyds Knob formation have not been understood. Stylolite-seams, small caverns, and minature faults are other features which owe their genesis to solution within the formation.