Ergotization of *F. majalis* kept the melanophores in the concentrated state without stopping the leucophore changes. This confirmed that the leucophores are functionally individual, rather than integral parts of the melanophores with which most are combined.

They do not (in *F. majalis*) depend on the pituitary for mediation of their responses.

* A fuller report of the effects of ergotamine on the several chromatophores in this species is in preparation for publication elsewhere.


*DISTORTION OF STRATIGRAPHIC THICKNESSES DUE TO FOLDING*

**BY ERNST CLOOS**

**DEPARTMENT OF GEOLOGY, THE JOHNS HOPKINS UNIVERSITY**

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*Introduction.*—Discussions of causes or mechanism of folding include as one vital component the thicknesses of the folded strata. Geosynclines, troughs or furrows are regions in which sedimentation has led to greater stratigraphic thicknesses and out of which folded zones, like the Appalachians, emerge. Thousands of papers have been written with the assumption that thicknesses as measured today are indicative of and permit conclusions of depths of troughs, basins of sedimentation, location of geosynclines, correlation of increase or decrease of thicknesses of formations and many others. Swells and deeps within geosynclines have been discussed and Schuchert’s paleogeographic maps are well known to every geologist. The concept of the geosyncline has become one of the pillars on which tectonic speculation rests. The author, however, feels obliged to cast some serious doubts on the underlying assumptions which are contained in the determination of stratigraphic thicknesses.

The general assumption may be phrased simply as follows: “Folding
(of the Appalachian or Alpine type) occurs in troughs or geosynclines where sediments are thick." But the question may also be put as follows: "Sediments are thick because they are folded." Little attention has been paid to the latter possibility and nobody as yet has eliminated it definitely. The author realizes, of course, that lateral shortening leads to thickening of the crust. Thickening of beds in anticlinal crests has long been recognized but the question arises whether or not thicknesses as measured in folded regions are thicknesses of deposition. In the following the author tries to show that "established" sections may be incorrect and that much of our knowledge of geosynclines may be based on alarmingly scant evidence.

Method of Investigation.—If stratigraphic thicknesses as measured today do not indicate thickness of sedimentation or depths of basins, they must be altered secondarily during folding. This leads to an investigation of deforming processes and quantitative determinations of deformation. The second step in the analysis consists of a comparison of measured thicknesses as described in the literature with known deformational distortion. Incidental to this phase is a critical analysis of some of the better known recorded thicknesses.

The author cannot possibly treat the enormous literature comprehensively here and only wishes to call attention to some of the principles involved. He feels justified in presenting the data because the problem is vital and far-reaching and the consequences should be called to the attention of the field geologist who deals with folded sediments.

The discussion is restricted to a rather small area in the Appalachians but applies everywhere. Quantitative measurements of the deformation of oölites were undertaken in Maryland and Pennsylvanina in Cambro-Ordovician limestones under a grant by the Geological Society of America. A detailed and comprehensive account on that work will follow later.

Folding.—Folding is meant to include the formation of folds of any kind, the bending of strata into anticlines and synclines whether symmetrical, overturned, recumbent, parallel or isoclinal. It includes the formation of a flow cleavage more or less parallel to the axial plane and relative movements on these planes. Shear folds and rock flowage as shown in thickening and thinning of beds within portions of folds is included. Deformation by fracturing, faulting, jointing, etc., are excluded for the present purpose.

Inasmuch as the distortion of stratigraphic thickness forms the main topic of discussion, such processes as may contribute to this distortion are included.

Rock Flowage.—Rock flowage is that portion of non-elastic deformation which occurs without fracturing. It includes rearrangement of minerals (recrystallization), formation of flow cleavage, migration of materials from limb to crest in a fold, elongation of components like ooids, pebbles,
fossils or amygdules. It is rarely entirely free from minute fracturing as seen in quartz grains, undulatory extinction or mineral cleavage. By flowage, the author means to describe the process which deforms beds without destruction of continuity of bedding. Intensity of flowage varies greatly and bedding may seem entirely unaffected or in intense deformation may be completely obliterated as, for instance, in crystalline schists. But inasmuch as no geologist places much confidence in measurements of stratigraphic thicknesses in recrystallized rocks, they are not here discussed. All formations included here are known as generally non-metamorphic and fossiliferous.

Flowage manifests itself in rearrangements of minerals at varying degrees of intensity, and in close relation to the folds in which it takes place. It culminates in flow cleavage which becomes prominent if the reorientation is sufficiently intense. Systematic investigation of oölitic limestones west of South Mountain in Maryland has furnished quantitative data on the amount of deformation necessary to make cleavage visible. The minimum ratio of the long axis of an elongated ooid over the shortest axis is 1.25:1, if cleavage is barely visible in the field. A ratio of 2:1 shows excellent cleavage and it reaches 7:1 beyond which ooids cannot be measured because of their destruction.

In quartzites deformation is also visible and strongly elongated quartz grains have been measured. The micas, however, "lubricate" the system and protect the quartz. If deformation is sufficient, quartz schists occur.

A systematic investigation of flowage in sandstones and quartzites in the central Appalachians by R. Fellows is well under way. In the Weverton quartzite, elongations of well-rounded quartz grains reach 2:1 without recrystallization of the entire rock. Cleavage is coarse but well visible, bedding is uninterrupted.

In shales cleavage is readily formed and measurements of crinoid stems in the Martinsburg shale show elongations of 2:1 and more.

In several hundred thin sections studied so far, cleavage is without exception in the direction of flowage. It contains the largest and mean axis of the deformation and is perpendicular to the smallest axis. This relation can easily be seen in deformed ooids and can be measured accurately wherever known shapes are available. Its intensity increases with increasing axial ratio.

If this ratio is 4:1, the extension of an originally spherical body is 100% of its original diameter. The present grain is twice as long and one-half as wide. Other ratios permit determination of the proportional amount of deformation. This distortion takes place by flowage, and the individual units, their boundaries and primary structures can still be studied.

**Flowage, Cleavage and Bedding.**—Since flowage results in cleavage, such flow cleavage becomes an important criterion in the analysis of the dis-
tortion of a bed. Where cleavage transects bedding at high angles, the beds have thickened, as is well known in all anticlines or synclines. Crests of folds are usually thicker than the limbs and in these crests cleavage is at high angles to bedding. On the other hand, limbs of folds are thinner and cleavage is at low angles or parallel to the bedding planes. Competent beds thicken less than incompetent ones, show cleavage less distinctly, and deformation ratios are smaller. Measurements of oolites along the western foothills of South Mountain in Maryland and Pennsylvania show, as a rule, that cleavage transects bedding at high angles. In this region, which comprises the entire Cambro-Ordovician sequence, exaggerated thicknesses can be expected.

Distorted Thicknesses.—If a type section has been measured at that area of an anticline at which beds are transected by cleavage at large angles (greater than 45 degrees), it can safely be assumed to be exaggerated. Thicknesses measured along limbs of folds are most likely too thin and certain incompetent formations may even be missing if they are adjacent to competent ones. A comparison of such thicknesses has led to the conclusion that depressions and swells existed within the geosyncline which has received the sediments.

A few examples taken from the literature will show the reliability of such conclusions and the necessity of a careful structural analysis in each section which is measured.

The lower Cambrian Weverton sandstone or quartzite was so named by Keith1 in 1894. This author estimated a thickness of 500 feet at Blue Ridge and 300 feet at Catoctin Mountain. Stose2 in 1909 writes: "The thickness cannot be accurately determined but their relative positions are shown in the columnar sections. The total thickness of the formation, computed from dips and width of outcrop is about 1250 feet. The rocks are so sheared and metamorphosed that the original bedding and even character of the original sediment cannot be determined."

South Mountain is a highly asymmetric anticline overturned westward and the distortion of bedding mentioned by Stose points toward a high angle of intersection between bedding and cleavage. It seems far from coincidental that the estimates of the two authors vary between 1250 and 300 feet from the crest and limb of the same anticline within one formation.

The Harpers shale is above the Weverton sandstone and was named by Keith from Harpers Ferry, West Virginia. In the above-mentioned report that author states that "... in no one (of the exposures) can the thickness be measured with any degree of accuracy, for they are folded and twisted beyond description. At Harpers Ferry, where the lithological exhibition is complete, the section is a hopeless tangle. The cleavage planes dip 60 to 80 degrees to the southeast, but the bedding can readily be traced in
every direction and at every angle. No measure of thickness of any value whatever can be obtained here.

"Making a liberal allowance for unrepresented portions and judging somewhat from the breadth of its outcrops, a probable thickness of 1200 feet can be assigned to the formation."

Stose describes the Harpers formation on the road from Waynesboro to Monterey (Pennsylvania) within the Chambersburg quadrangle as follows: "In the Chambersburg quadrangle the most accurate determination of the thickness is obtained at the ends of the plunging anticlines northeast of Waynesboro and north of Fayetteville where the dips are low and uniform." The estimate given here is 2750 feet and the author added that "... in most places the rock is a schist."

The difference between the two estimates is more than 100% and in the new road cuts east of Waynesboro the cleavage intersects bedding at an angle of about 90 degrees.

In Adams County, Pennsylvania, Stose describes a similar situation: "... sericite ... is arranged parallel to the planes along which movement of the particles took place during compression and gives the rock its schistose character." Here cleavage intersects bedding at an angle of 90 degrees. The thickness of the formation is estimated as 3000 feet which is still more than near Waynesboro.

The Antietam schist overlies Harpers schist and Keith (14th report) states that the best locality for thickness measurements is at the north end of Blue Ridge. His estimate is between 500 and 700 feet at Front Royal. He states, however, that "... no better measures than those are known, and it would be hazardous to draw deductions from them." Stose comes to similar conclusions and estimates about 500 feet for the southern part and 800 feet in the northern part of the Chambersburg quadrangle. At White Rock the cleavage dips 35 degrees east, bedding 80 degrees west. The angle of 65 degrees points toward an exaggerated thickness.

The Tomstown dolomite was named after Tomstown north of Waynesboro by Stose. "The thickness computed from width of its outcrop and dip of its beds is about 1000 feet. The dip of the beds is 10 degrees south under red shale of the overlying Waynesboro formation." This thickness is also computed in an anticlinal nose. An investigation of oolite deformation at this locality shows intense elongation within the axial plane. The ratio is approximately 4:1, thus indicating an exaggerated thickness of 100%.

The Waynesboro formation as named by Stose overlies the Tomstown dolomite at Waynesboro. The beds are flat lying and were computed to be 1000 to 1750 feet thick in this area which is also a portion of the same anticline.
The Elbrook formation was named by Stose after the village of Elbrook, 5 miles northwest of Waynesboro (Chambersburg quadrangle). Here two computations from an asymmetrical syncline furnished a mean thickness of 3000 feet. Unfortunately, the author did not name the two values. This region is in an area in which oolite ratios vary between 1.5:1 and 2:1. Minor folding obscures the picture and an evaluation of this estimate is not yet possible.

The overlying Conococheague limestone was first measured in a section west of Scotland (Chambersburg quadrangle) as 1635 ft by Stose. Here bedding dips 70 to 80 degrees west and a strong transecting cleavage dips 20 to 30 degrees east. An excellent oolite bed is exposed east of the railroad bridge and its deformation was determined in thin sections. The average ratio of the longest over the shortest axes of ooids is 2.04:1 and the actual amount of extension in reference to a unit sphere is 55%. The bedding planes are intensely crumpled, offset and disarranged but still excellently visible. Inasmuch as the angle between maximum elongation and bedding is between 80 and 90 degrees, it stands to reason that the beds have been thickened by 50% and thus the original thickness exaggerated by at least 540 feet.

Many more examples can be cited for the whole paleozoic section of the Appalachian area. It seems strange that so many type sections have been computed or measured without structural considerations or description of the attitude of cleavage in relation to bedding. There seems little doubt that many such sections should be reexamined. Conclusions drawn from them are of rather doubtful value.

**Distorted Bedding.**—If cleavage as a plane in which flowage takes place transects bedding, it tends to distort it and finally obliterate it. Where cleavage is intense it provides avenues for the introduction of new materials like quartz, calcite or dolomite. The whole rock tends to appear different from the same formation elsewhere. Fossils become distorted or obliterated. Even changes in "lithology" may be produced by transecting cleavage planes. One of the best examples may be found in Hagerstown valley west of South Mountain uplift. The limestones west of the Martinsburg shale belt differ from those in the east probably less because of lithologic changes but because the deformational ratio and thus the intensity of cleavage increases from west to east. West of the Martinsburg shale it does not exceed 1.5:1 and to the east it reaches 7:1 in the Conococheague limestone. Many workers have also noted that in the east fossils are scarce!

**Conclusions.**—Wherever thicknesses are measured or computed, they are cited as observed in the field and listed. Thus after insertion into the literature, these values are used by others as basis for far-reaching conclusions, correlations and speculations. Once "established" such values
THE PERMUTATION GROUPS OF A GENERAL DEGREE

BY G. A. MILLER

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF ILLINOIS

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Although group theory as an autonomous science originated with the study of permutation groups these groups present many difficulties which have not yet been overcome notwithstanding the fact that when only groups of small degrees are considered the study of the permutation groups is remarkably simple. One reason why the permutation groups of small degrees were the first to receive much attention is that these groups are the only ones which require consideration in the theory of the algebraic equations of small degrees. As these equations naturally were the first to