Reports

Strike-Slip Displacement on Faults in Triassic Rocks in New Jersey

Abstract. The Hopewell and Flemington faults in New Jersey are inferred to extend 10 to 15 miles or more farther north than their previously mapped northward limits. The Hopewell fault, previously known to show dip-slip displacement of 10,000 feet or more, is inferred to include as well a right-lateral strike-slip component of 12 miles on the basis of apparent displacement along its northern extension of the crestal traces of two partial anticlines which are held to be displaced segments of the same transverse structure, here called the Somerville anticline. An unknown amount of strike-slip displacement may have occurred also on the Flemington fault, if the apparent offset of the Ramapo fault at the northwestern border of the Triassic outcrop belt is explained as the result of displacement of a formerly continuous northeast-trending, southeast-dipping fault by a north-trending vertical extension of the Flemington fault.

I have recently examined the tectonic relationships of the transverse warped structures in the Triassic rocks of Connecticut, New York, and northern New Jersey (*1*). In the Connecticut Valley Triassic belt, two adjacent transverse synclines are always separated by an intervening transverse anticline. These anticlines can always be identified, even though they may be much faulted and displaced. Because of the remarkable similarity of the transverse synclines in the Connecticut Valley with those in the New Jersey–New York area, I suspected that transverse anticlines likewise exist between the New Jersey synclines, but that they have gone unnoticed in spite of recognition of the synclines. Accordingly, on 9 April 1961 I carried out a brief field reconnaissance in the area west of the southwest end of the Watchung syncline, between Somerville, Flemington, and the northwestern boundary (Ramapo) fault in southwestern New Jersey, to examine the localities between known transverse synclines (*2*). The result of this reconnaissance was the discovery of two previously unrecognized anticlinal structures, which, if they are considered to be displaced parts of a single feature, provide evidence of a northward extension of the Hopewell fault and yield indications of substantial right-lateral strike-slip components of displacement on it. Evidence of an analogous northward extension of the Flemington fault was also found; this fault likewise may show comparable strike-slip displacement. Strike-slip movements of this magnitude have not been reported previously in the Triassic rocks of the eastern United States.

Girard Wheeler (*2*) named four synclines in the New Jersey Triassic: Watchung, New Germantown, Sand Brook, and Hunterdon. The Watchung structure is well known; the last three are labeled on Fig. 1. Wheeler identified no transverse anticlines between these synclines. As the axes of the first three trend northwest-southeast, they are truly transverse; the Hunterdon trends east-west and should be considered longitudinal, a type not recognized by Wheeler.

An anticline whose crestal trace is found near Somerville is named for that town. The crest is defined by oppositely dipping strata of the Brunswick formation (Fig. 1), but generally only the northeast limb is present. Strata of the common (northeast) limb between the Somerville anticline and Watchung syncline strike N 45° W and dip 20° NE. The Somerville anticline can be followed in the Brunswick beds for only a short distance to the northwest and southeast; it presumably is terminated by faults. The southwest limb of the Somerville anticline is generally absent.

If the Somerville anticline is genetically related to the Watchung syncline, then exact analogy with the Connecticut Valley pattern emerges. If this pattern is indeed present in New Jersey, then a transverse anticline should be located northeast of the New Germantown syncline. A road traverse northeastward from the axis of the New Germantown syncline revealed scattered outcrops of Triassic sandstone with strike of N 45° W (perpendicular to the Ramapo fault) and dips ranging from 50° SW near the synclinal axis to 30° SW further away from this axis to the northeast. Still further northeast is a conical hill called Mount Paul (Fig. 1) on which flat-lying Triassic conglomerate overlies vertical Ordovician slates.

I believe that Mount Paul marks the crest of a transverse anticline which lies northeast of and parallel to the New Germantown syncline. No northeastern limb of this structure can be seen near Mount Paul. This structure occupies only a very narrow area adjacent to the Ramapo fault, for Precambrian rocks occur less than half a mile southeast of Mount Paul.

If the structure of Mount Paul is anticlinal, the next inquiry concerns its possible relationship to the Somerville anticline. The Connecticut Valley pattern [single transverse anticline between two adjacent transverse synclines, both extending to the border fault (*3*)], if present in New Jersey, as is here supposed, dictates the inference that the Somerville and Mount Paul anticlinal structures were once continuous and should therefore be considered as displaced parts of one larger feature. This interpretation gains credence from the fact that the Mount Paul structure with its crest and *southwestern* limb (leading to New Germantown syncline) provides exactly the needed "missing parts" to complete the Somerville structure, which generally shows only a crestal area and a northeastern limb (leading to the Watchung syncline).

Assuming the original continuity of the Somerville and Mount Paul anticlinal structures, then 12 miles of right-lateral strike-slip displacement must have occurred on a north-trending fault which connects their cut-off ends. The position of such an inferred fault lies due north of the place where the Hopewell fault has been terminated on Kümmel's map (Fig. 1) and is also in line with an offset in the Ramapo fault and

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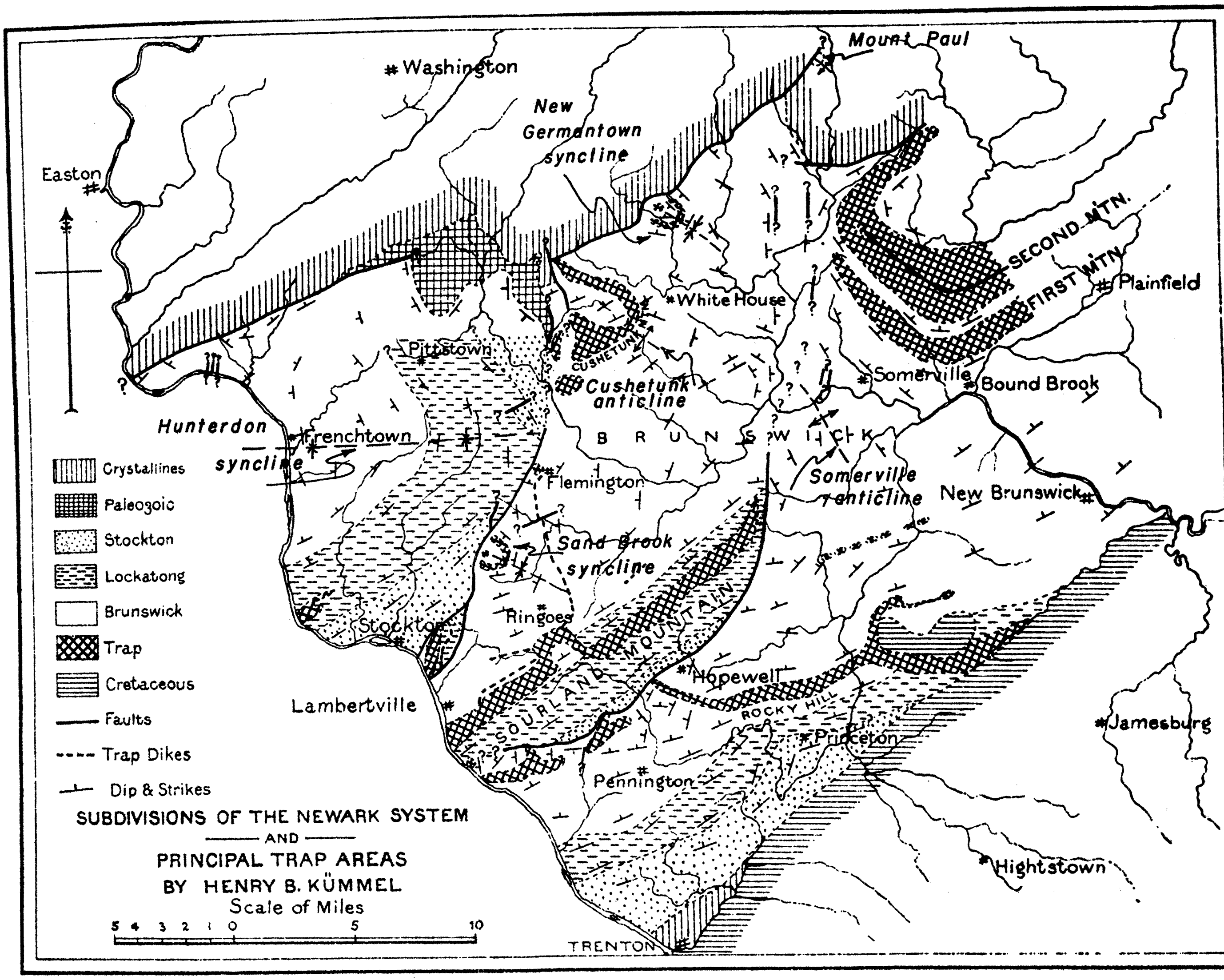
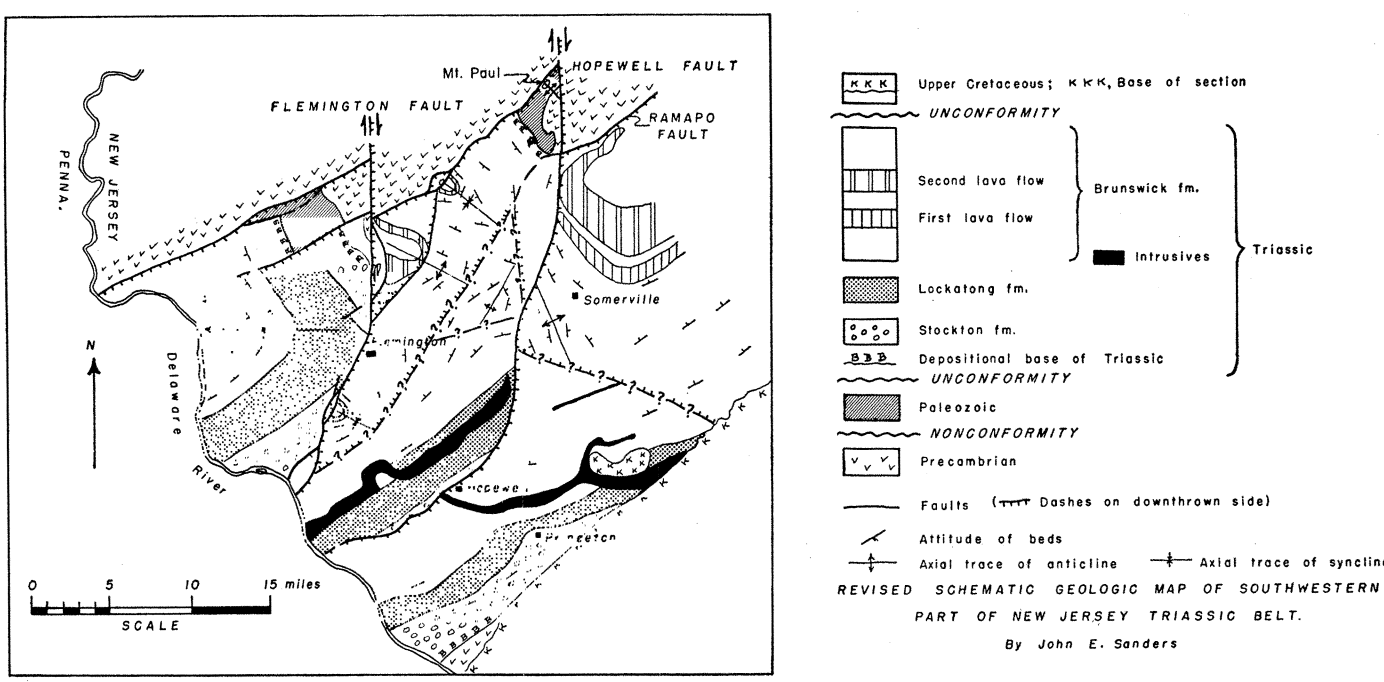
Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to contributors" [*Science* **125**, 16 (1957)].





Figs. 1 and 2. (Top) Geologic map of the southwestern part of the New Jersey Triassic belt [after Kümmel (1897), with names of folds given by Wheeler (1937) and location of Mount Paul added by Sanders]. (Bottom) Revised schematic geologic map of the southwestern part of the New Jersey Triassic belt showing major structures and inferred northward extensions of Hopewell and Flemington faults. Relationships at these faults to "offsets" of the Ramapo fault are shown according to the interpretation of strike-slip displacement on the Hopewell and Flemington faults.

a prominent linear valley in the Precambrian rocks. The "offset" may represent an original en echelon arrangement, but owing to its regional continuity elsewhere and the logical reconstruction of the unity of the two transverse anticlinal structures, however, I prefer the interpretation that the Ramapo fault was originally continuous and has been displaced.

The supposed right-lateral strike-slip offset of a formerly continuous Ramapo fault amounts to only 6 miles. The apparent discrepancy with the 12-mile offset based on the displaced anticlinal crests can be explained if the Hopewell fault, with its large up-on-the-west dip-slip component of displacement (*4*) is extended northward. Up-on-the-west dip-slip movement on a north-trending vertical fault would offset a formerly continuous northeast-trending, southeast-dipping Ramapo fault to the *south* on the west side of the north-trending fault. Thus, the apparent strike-slip offset of the Ramapo fault would be less than the true strike-slip component (as measured by the anticlines) by an amount equal to the southward displacement caused by dip-slip movement. The magnitude of this southward dip-slip displacement (6 miles, if the 12-mile figure is correct) is controlled only by two variables: (i) the amount of dip-slip displacement on the vertical north-trending fault (Hopewell fault extended) and (ii) the dip of the Ramapo fault. Stratigraphic evidence north of Somerville suggests that the amount of dip-slip displacement on the vertical north-trending fault is approximately 15,000 feet; with this figure, the dip of the Ramapo fault can be calculated to be 31°. Alternatively, if one assumes that the Ramapo fault dips more steeply, say 55°, then the dip-slip displacement on the north-trending fault must be 31,680 feet.

If the Hopewell fault continues northward and contains large strike-slip displacement, as is argued here, then a comparable northward extension and similar strike-slip displacement may also be inferred for the nearby Flemington fault. The case for the Flemington fault is less direct than that for the Hopewell fault, for the only known reference surface which extends across the Flemington fault or its inferred northward extension is the Ramapo fault. The originally continuous nature of this surface is debatable, for the observed offset arrangement northeast of Pittstown and north of Flemington (Fig. 1) might be regarded as an initial en echelon pattern. If, however, one assumes the original continuity of the Ramapo fault here, as north of Somerville, then it appears to have been offset along a fault which lies due north of the termination on Kümmel's map of the Flemington fault (Fig. 1). A relationship exactly similar to the one just described for the supposed northward extension of the Hopewell fault may therefore exist north of Flemington (Fig. 2). Like the Hopewell fault, the Flemington fault shows large up-on-the-west dip-slip displacement (*5*). If only dip-slip movement has occurred on this fault, then a northward extension of it would offset a formerly continuous southeast-dipping Ramapo fault to the *south* on the western block, not to the north, as is observed. This "opposite" effect is taken as suggestive evidence that the Flemington fault extends northward of its previously supposed termination and that substantial right-lateral strike-slip displacement has accompanied the dip-slip displacement on it (*6*).

JOHN E. SANDERS

Department of Geology, Yale University, New Haven, Connecticut

References and Notes

1. J. E. Sanders, *Trans. N.Y. Acad. Sci.* **23** (2), 119–132 (1960); *J. Geophys. Research* **66** (8), 2557–2558 (1961).
2. G. Wheeler, *J. Geol.* **47**, 346–356 (1939).
3. G. Wheeler, *ibid.* 342–346; 356–359; J. E. Sanders, field observations.
4. H. B. Kümmel, *N.J. Geol. Survey, Ann. Rept. State Geologist for 1896* (1897), pp. 107–108.
5. ———, *ibid.*, pp. 108–109.
6. I am much indebted to Dr. Fred A. Donath for critical comments on the manuscript, which have greatly strengthened the presentation of the arguments contained here.

15 September 1961

Dehydrogenases of Neurospora crassa

Abstract. Malate, isocitrate, glucose-6-phosphate, and 6-phosphogluconate dehydrogenases of the homogenate prepared from the mycelia of several wild strains of *Neurospora crassa* have been subjected to zone electrophoresis in starch gel. Four electrophoretically different malate dehydrogenases, a single isocitrate dehydrogenase, three glucose-6-phosphate dehydrogenases, and two 6-phosphogluconate dehydrogenases were obtained regardless of the strain or the media in which the organism was grown.

The existence of lactate dehydrogenase in electrophoretically different forms has been noted in purified material (*1*). The finding of several components of this enzyme in animal organs with paper electrophoresis has stimulated wide interest in this phenomenon (*2*). The use of electrophoresis in starch gel for the separation of the dehydrogenases of mammalian organs also yielded evidence of multiplicity of enzymes (*3, 4*). To eliminate the possibility of this multiplicity being caused by indiscriminate mixing of different types of cells in organ homogenates, it has been shown with tissue-cultured mammalian cells that the multiplicity of several dehydrogenases is demonstrable in cytologically uniform material (*4*). To strengthen the evidence obtained by electrophoresis, sufficient quantities of the components of a single dehydrogenase must be secured for other studies. These studies are necessary to establish the chemical relationship between the components. In a survey of microorganisms which can be harvested conveniently in quantity, *Neurospora crassa* was found to exhibit multiplicity of dehydrogenases. This report deals with the experimental evidence of such multiplicity and the persistence of this phenomenon in several strains grown in different culture media.

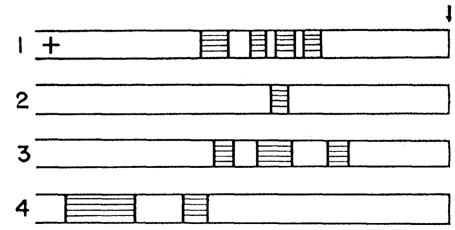


Fig. 1. Dehydrogenases of *Neurospora crassa* mycelia after fractionation by electrophoresis in starch gel and direct visualization of enzymic activity in the gel. Substrates used were: 1, malate; 2, isocitrate; 3, glucose-6-phosphate; and 4, 6-phosphogluconate. Arrow indicates the location of the sample of mycelia homogenate.

The following strains of *Neurospora crassa* were obtained from the American Type Culture Collection: 9279, 12758, 10767, 10336, 10337, 10815, and 10816. Strain 5297 was a gift of H. J. Blumenthal. Minimal medium (*5*), Sabouraud medium (Difco), and a medium containing 5-percent sucrose and 0.5-percent each of malt extract and yeast extract were used. Cultures were grown from conidial inocula in 1 liter of medium in a Fernbach flask rotated at 150 rev/min at 28° to 30°C. Mycelia were harvested after 5 to 10 days, collected on a Buchner funnel over a layer of gauze, washed