Characterization of Appalachian faults

Robert D. Hatcher, Jr.
Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37996-1410
and Environmental Sciences Division, Oak Ridge National Laboratory,* P.O. Box X, Oak Ridge, Tennessee 37831
A. L. Odom
Department of Geology, Florida State University, Tallahassee, Florida 32306
Terry Engelder
Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania 16802
D. E. Dunn
School of Natural Sciences and Mathematics, University of Texas at Dallas, Richardson, Texas 75083
D. U. Wise
Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts 01003
P. A. Geiser
Department of Geology and Geophysics, University of Connecticut, Storrs, Connecticut 06268
Steven Schamel
Earth Sciences and Resources Institute, University of South Carolina, Columbia, South Carolina 29208
S. A. Kish
Department of Geology, Florida State University, Tallahassee, Florida 32306

ABSTRACT

This study presents a classification/characterization of Appalachian faults. Characterization factors include timing of movement relative to folding, metamorphism, and plutonism; tectonic position in the orogen; relations to existing anisotropies in the rock masses; involvement of particular rock units and their ages, as well as the standard Andersonian distinctions. Categories include faults with demonstrable Cenozoic activity, wildflysch-associated thrusts, foreland bedding-plane thrusts, premetamorphic to synmetamorphic thrusts in medium- to high-grade terranes, postmetamorphic thrusts in medium- to high-grade terranes, thrusts rooted in Precambrian basement, reverse faults, strike-slip faults, normal (block) faults, compound faults, structural lineaments, faults associated with local centers of disturbance, and geomorphic (nontectonic) faults.

INTRODUCTION

This paper is a synopsis of a study (Odom and Hatcher, 1980) to evaluate the significance of Appalachian faults in a regional context (see Williams, 1978 and Hatcher et al., 1988 for distributions and fault geometries), provide well-defined criteria for classification, ascertain the genetic significance, clarify their nomenclature, and classify the faults of the Appalachian orogen.

Accordingly, Appalachian faults have been grouped into 13 categories by using characteristics that include the descriptive properties, genetic inferences, tectonic setting, and potential as geologic and seismic hazards. Of necessity, this is a genetic classification and may be partly subjective. The goal of this classification is to improve communication about the kinds of Appalachian faults and where they occur in the orogen, and to understand their formation. We believe that this scheme can be generalized to most other orogens but also recognize the pitfalls of overclassification discussed by Boyer and Elliott (1982). A related paper (Wise et al., 1984) discussed the terminology of fault rocks.

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400.

The Appalachian orogen is complex, and attempts to categorize all the faults in it are difficult because of their variety. However, faults constitute one of the principal mechanical discontinuities of the Appalachians that can be grouped spatially and temporally. Each group reflects the complex interaction of the change in mechanical properties of the orogen as it responded to changing stress, temperature, and geometric properties throughout its long history. This history progressed from early extensional block faulting along the Precambrian Laurentian margin to a period of syndepositional synmetamorphic Taconic thrusts. As deformation proceeded, Precambrian Grenville basement apparently sheared along the leading edge of the Laurentian craton as external terranes were accreted and overthrust onto it. Postmetamorphic faulting transported Taconic rocks over the foreland and incorporated some of the miogeoclinal wedge sediments within the thrust sheets. Acadian and then Alleghanian faults overprinted all earlier structures. Acadian and Alleghanian metamorphism and plutonism also increased the degree of complexity, while providing reference time lines to bracket deformations. Additionally, various generations of folds and other penetrative and nonpenetrative structures were formed as the orogen developed (Hatcher and Viele, 1982; Williams and Hatcher, 1983). Each reflected different rheologies and conditions of emplacement that varied both with time and space. As the orogen was constructed on the Precambrian eastern margin of North America, older faults, being weakness planes, were reactivated. Many of these compound faults underwent multiple reactivation to form the longest lived elements in the tectonic framework of the orogen. As the Appalachian cycle ended, the Mesozoic Wilson cycle began, and major block-fault terranes reappeared, to be superseded by the Tertiary-Holocene phase of compression (e.g., Roper, 1979; Richardson et al., 1979). Superimposed upon these faults and folds are the superficial local deformations associated with geomorphic and other phenomena.

CRITERIA UTILIZED TO DISTINGUISH FAULT CATEGORIES

No single criterion can determine a unique category for each fault within the orogen, so we selected several, each of which can be illustrated

 GEOLOGY, v. 16, p. 178–181, February 1988

by faults which, on the basis of one or more criteria, are relatively pure end members. Most faults occur as intermediate types.

Factors that are used to categorize fault groups include (1) standard Andersonian (Anderson, 1942) orientations producing shortening, extension, and strike-slip motions; (2) the relative timing of fault movement with respect to other processes in the orogen such as folding, plutonism, and metamorphism; (3) the tectonic position of the fault with respect to the metamorphic core and the foreland of the orogen; (4) the relation of the fault to anisotropies within the rock masses, particularly bedding; (5) the involvement of preexisting basement. For example, the distinction between Grenville basement and younger crystalline masses was preserved where possible. A separate group of Cenozoic faults was established because of the practical significance of these structures and their importance to the modern-day human activities. In addition, a class of structures that may be more geomorphic than tectonic was recognized because of the potential confusion on the outcrop scale with the true tectonic faults of recent displacement. Taconic-type submarine slab thrusts also were separated.

CHARACTERISTICS AND DISTRIBUTION OF FAULTS IN THE APPALACHIAN OROGEN

The groupings of faults that follow are intended to cover the entire spectrum of faulting in the Appalachian orogen, including the post-Paleozoic faults that occur here. Many Appalachian faults might be placed in more than one category in other classifications. By using the five factors listed above, most faults can be reasonably placed in one of the 13 groups outlined below. We also recognize that some overlap between fault types may occur; e.g., between Groups 3, 4, and 5.

Group 1: Cenozoic Faults

This group includes mostly high-angle reverse faults that occur primarily where Coastal Plain strata onlap the Piedmont in the southern and central Appalachians (Mixon and Newell, 1977; Prowell and O'Connor, 1978; Reinhardt et al., 1980). However, numerous Cenozoic faults may exist elsewhere in the Appalachian orogen; it is difficult to recognize them because of the absence of Cenozoic or Mesozoic rocks. Excluded from this group are faults known to be associated with recent near-surface stress release, such as postglacial pop-ups, sheeting, local reactivation of old fault zones in man-made excavations, and landslides.

Group 2: Thrust Faults in Wildflysch

Such faults include thrust sheets that are associated with wildflysch sedimentation. All known faults of this group appear to be of Middle Ordovician age and are located between the eastern margin of the foreland and the basement massifs, and between Pennsylvania and Newfoundland (Williams, 1978). The southernmost of these thrust sheets is the Hamburg klippe (Root and MacLachlan, 1978; Lash and Drake, 1984). Others occur to the north in eastern New York, western Vermont, Quebec, and Newfoundland (Rowley and Kidd, 1980).

Group 3: Bedding-Plane Thrusts

This group formed during Ordovician or younger thin-skinned deformation of the Appalachian foreland and is characteristic of the Appalachian Valley and Ridge and Cumberland–Allegheny Plateau provinces (Gwinn, 1964; Harris and Milici, 1977). Fault displacement is commonly parallel to bedding surfaces and cuts up-section in the direction of tectonic transport by ramping across competent layers from lower to higher weak zones (Rich, 1934; Chapple, 1978). The sense of vergence is always toward the craton, except in the out-of-sequence thrusts in the Cumberland–Allegheny Plateau and "delta" (triangle) structures (anticlines containing oppositely dipping thrusts) (Hatcher et al., 1982).

Group 4: Premetamorphic to Synmetamorphic Thrusts in Medium- to High-Grade Metamorphic Terranes

These thrusts occur throughout much of the Blue Ridge and Piedmont of the southern and central Appalachians (Hadley and Goldsmith, 1963; Hatcher, 1978; Hatcher and Williams, 1986), as well as in the western fringes and central parts of the metamorphic core in New England (Harwood, 1975; Hall and Robinson, 1982). These faults have been overprinted by Devonian and later deformation and metamorphism and probably originated by a variety of fault mechanisms. Some were emplaced initially as thin-skinned thrusts involving unmetamorphosed sedimentary rocks that were later metamorphosed. Others are synmetamorphic faults that have mylonites along their contacts, indicating movement at considerable depths and elevated temperatures.

Group 5: Postmetamorphic Thrusts

These thrusts occur in the medium- to high-grade parts of the Blue Ridge and Piedmont provinces (Bryant and Reed, 1970; Hatcher, 1972, 1981; Griffin, 1974; Hopson and Hatcher, 1988) and in the interior parts of the New England Appalachians (Dixon and Lundgren, 1968; Harwood, 1975; Ratcliffe and Harwood, 1975; Hall and Robinson, 1982). These faults juxtapose different metamorphic isograds and in places exhibit mylonites that locally transpose older foliations and contain retrograde mineral assemblages.

Group 6: Thrusts Rooted in Retrograded Crystalline Basement Rocks That Generally Transport Grenville Basement

These basement rocks are in an environment in which cover rocks are either unmetamorphosed or only slightly metamorphosed, and they occur along the boundary between the foreland and metamorphic core (see Drake, 1970, 1978; King and Ferguson, 1960; Cloos, 1971; Wickham, 1972; Harwood, 1975). The actual Grenvillian metamorphic grade is high, and retrogression associated with Appalachian events is minimal for this group. Apparently, these basement rocks were derived from the eastern edge of the Laurentian craton and transported over it as rootless massifs.

Group 7: High-Angle Reverse Faults

These faults occur as small structures and are common throughout the Appalachians. However, their mechanics of formation are generally identical to those of the thrust faults. In making them a separate category, we assumed that Group 7 faults have a relatively uniform steep dip. Large, high-angle faults in southeastern New England would be in this category, including faults in the Boston, Norfolk, and Narragansett basins (Billings, 1976; Mosher, 1983).

Group 8: Strike-Slip Faults That Formed at Different Times

These faults exist throughout the Appalachians. Late Paleozoic strike-slip faults have been known in the Maritime Appalachians for many years and include the Cabot, Glooscap, and Cobequid faults (Eisbacher, 1969; Williams, 1978). In addition, there are transcurrent faults, of which the Cross Mountain fault in Tennessee is probably the best example (King and Ferguson, 1960), and tear faults that bound thrust sheets within the Valley and Ridge and Cumberland Plateau, e.g., the Jacksboro and Russell Fork faults. Numerous cross-strike discontinuities of variable displacement have also been identified (Wheeler et al., 1979). Until recently, strike-slip faulting has not been thought to have been significant in Appalachian tectonic history. However, large-scale, along-strike transport of suspect terranes demonstrated by paleontological and paleomagnetic data in the United States and Canadian Cordillera (Coney et al., 1980; Irving, 1979) suggests that throughout major parts of their history, the internal parts of the Appalachians also probably underwent major strike-slip faulting (Bobyarchick, 1981; Williams and Hatcher, 1983; Secor et al., 1983; Mosher, 1983). Paleomagnetic studies by Kent and Opdyke (1978, 1980) and Van der Voo (1983) provided additional evidence that significant amounts of strike-slip motion occurred in the Appalachians.

Group 9: Normal (Block) Faults of Mesozoic Age

These faults occur in the Canadian Maritimes (Bay of Fundy), southern and central Appalachian Piedmont, and central New England, and beneath the Coastal Plain (Chowns and Williams, 1983). They were produced by rifting prior to the opening and spreading of the present Atlantic Ocean. All are brittle faults having steep dips at their present structural level, but they probably have listric geometries. They are commonly associated with terrestrial sedimentation and extrusion of basaltic flows. Similar block faults apparently formed at the beginning of the Appalachian cycle during opening of the Iapetus Ocean, but are now exposed only in eastern New York and western Vermont. Late Paleozoic block faults have also been identified in southeastern New England (Mosher, 1983).

Group 10: Compound Faults

These faults have undergone multiple episodes of movement or reactivation. In most cases, reactivation has resulted in a completely different style of deformation along the same fault in response to a reoriented stress field. Faults of this group are restricted to the metamorphic core of the Appalachians; the best documented examples are probably the Ramapo fault of New York and New Jersey (Ratcliffe, 1980) and the Brevard fault zone of the southern Appalachians (Hatcher, 1978). In many cases, these faults contain complex assemblages of fault rocks, e.g., mylonites, phyllonites, and later cataclasites, indicating that fault movement occurred under diverse P-T conditions.

Group 11: Structural Lineaments of Complex and Enigmatic Appearance

In many cases these lineaments are not true faults, but some occur along known faults and therefore constitute a class of features with more than one origin (e.g., see Wise, 1982). Faults of more than one kind can occur on the same lineament. Fractures with no previous shear displacement may also occur along lineaments (e.g., the Warwoman lineament, which crosses the Brevard fault zone; Hatcher, 1974). The Brevard fault constitutes a lineament traceable for several hundred kilometres. This is a significant fault in the southern Appalachians and has a long history of recurrent movement.

Group 12: Faults Associated with Local Centers of Disturbance

These faults occur near and are genetically linked to features such as igneous intrusions, cauldrons, diapirs, and crypto-explosive structures. All are local in extent, and most do not relate to any large-scale regional stress field. Most have nontectonic origins.

Group 13: Faults Related to Geomorphic Phenomena

This group includes mesoscopic-scale nontectonic faults that are primarily related to geomorphic or surficial processes. Their history is restricted to Quaternary time. Examples of Group 13 faults include those forming in saprolite, such as Fe-oxide-coated slickensided surfaces that appear faultlike but may not be traced below weathered zones, karst and other collapse structures, glaciotectonic structures, and faults resulting from mass-wasting processes, which produce shallow slip surfaces and occasionally may involve bedrock materials, pop-ups, and other near-surface phenomena related to stress release. Most of the latter are related to releases of high in situ stress which may or may not have a tectonic origin.

SUMMARY

The fault classification described here could be applied to most complexly deformed regions. The Appalachian orogen is well suited as a proving ground for any fault classification because of its antiquity and depth of exposure, the presence of most of the tectonic provinces found within orogens, and the detailed knowledge accumulated over the past 150 yr.

REFERENCES CITED

Anderson, E.M., 1942, The dynamics of faulting and dyke formation, with applications to Britain: Edinburgh, Oliver and Boyd, 191 p.

Billings, M.P., 1976, Bedrock geology in the Boston Basin, *in* Cameron, B.C., ed., Geology of southeastern New England (New England Intercollegiate Geological Conference Guidebook): Princeton, New Jersey, Science Press, p. 28–43.

Bobyarchick, A.R., 1981, The eastern Piedmont fault system and its relationship to Alleghanian tectonics in the southern Appalachians: Journal of Geology, v. 89, p. 335–347.

Boyer, S.E., and Elliott, D., 1982, Thrust systems: American Association of Petroleum Geologists Bulletin, v. 66, p. 1196–1230.

Bryant, Bruce, and Reed, J.C., Jr., 1970, Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee: U.S. Geological Survey Professional Paper 615, 190 p.

Chapple, W.M., 1978, Mechanics of thin-skinned fold and thrust belts: Geological Society of America Bulletin, v. 89, p. 1189–1198.

Chowns, T.M., and Williams, C.T., 1983, Pre-Cretaceous rocks beneath the Georgia coastal plain—Regional implication, *in* Gohn, G.S., ed., Studies related to the Charleston, South Carolina earthquake of 1886—Tectonics and seismicity: U.S. Geological Survey Professional Paper 1313, p. L1–L42.

Cloos, Ernst, 1971, Microtectonics along the western edge of the Blue Ridge, Maryland and Virginia: Baltimore, Maryland, Johns Hopkins University Press, 239 p.

Coney, P.J., Jones, D.L., and Monger, J.W.H., 1980, Cordilleran suspect terranes: Nature, v. 288, p. 329–333.

Dixon, H.R., and Lundgren, L.W., 1968, Structure of eastern Connecticut, *in* Zen, E-an, White, W.S., Hadley, J.B., and Thompson, J.B., Jr., eds., Studies of Appalachian geology: Northern and maritime: New York, Wiley-Interscience, p. 141–149.

Drake, A.A., Jr., 1970, Structural geology of the Reading Prong, *in* Fisher, G.W., Pettijohn, F.J., Reed, J.C., Jr., and Weaver, K.N., eds., Studies of Appalachian geology: Central and southern: New York, Wiley-Interscience, p. 271–291.

——1978, The Lyon Station–Paulings Kill nappe—The frontal structure of the Musconetcong nappe system in eastern Pennsylvania and New Jersey: U.S. Geological Survey Professional Paper 1023, 20 p.

Eisbacher, G.H., 1969, Displacement and stress field along part of the Cobequid fault, Nova Scotia: Canadian Journal of Earth Sciences, v. 6, p. 1095–1104.

Griffin, V.S., Jr., 1974, Analysis of the Piedmont in northwest South Carolina: Geological Society of America Bulletin, v. 85, p. 1123–1138.

Gwinn, V.E., 1964, Thin-skinned tectonics in the Plateau and northwestern Valley and Ridge provinces of the Central Appalachians: Geological Society of America Bulletin, v. 75, p. 863–900.

Hadley, J.B., and Goldsmith, Richard, 1963, Geology of the eastern Great Smoky Mountains, North Carolina and Tennessee: U.S. Geological Survey Professional Paper 349-B, 118 p.

Hall, L.M., and Robinson, Peter, 1982, Stratigraphic-tectonic subdivisions of southern New England, *in* St. Julien, Pierre, and Beland, Jacques, eds., Major structural zones and faults of the northern Appalachians: Geological Association of Canada Special Paper 24, p. 15–41.

Harris, L.D., and Milici, R.C., 1977, Characteristics of thin-skinned style of deformation in the southern Appalachians, and potential hydrocarbon traps: U.S. Geological Survey Professional Paper 1018, 40 p.

Harwood, D.S., editor, 1975, Tectonic studies of the Berkshire massif, western Massachusetts, Connecticut and Vermont: U.S. Geological Survey Professional Paper 888, 106 p.

Hatcher, R.D., Jr., 1972, Developmental model for the southern Appalachians: Geological Society of America Bulletin, v. 83, p. 2735–2760.

——1974, Introduction to the tectonic history of northeast Georgia: Georgia Geological Survey Guidebook 13-A, 59 p.

——1978, Tectonics of the western Piedmont and Blue Ridge: Review and speculation: American Journal of Science, v. 278, p. 276–304.

——1981, Thrusts and nappes in the North American Appalachian orogen, *in* McClay, K.R., and Price, N.J., eds., Thrust and nappe tectonics: Geological Society of London Special Publication 9, p. 491–499.

Hatcher, R.D., Jr., and Viele, G.W., 1982, The Appalachian/Ouachita orogens: United States and Mexico, *in* Palmer, A.R., ed., Regional geological synthesis: Boulder, Colorado, Geological Society of America, Decade of North American Geology Special Publication 1, p. 67–75.

Hatcher, R.D., Jr., and Williams, R.T., 1986, Mechanical model for single thrust sheets, Part I: Crystalline thrust sheets and their relationships to the mechani-

cal/thermal behavior of orogenic belts: Geological Society of America Bulletin, v. 97, p. 975–985.
Hatcher, R.D., Jr., Schamel, Steven, and Post, Paul J., 1982, Formation of duplex, imbricate, delta and other complex structures in thrust belts: Geological Society of America Abstracts with Programs, v. 14, p. 509.
Hatcher, R.D., Jr., Osberg, P.H., and Drake, A.A., Jr., Robinson, P., and Thomas, W.A., 1988, Tectonic map of the U.S. Appalachians, *in* Hatcher, R.D., Jr., Viele, G.W., and Thomas, W.A., eds., The U.S. Appalachians and Ouachitas: Boulder, Colorado, Geological Society of America, The Geology of North America (in press).
Hopson, J.L., and Hatcher, R.D., Jr., 1988, Structural and stratigraphic setting of the Alto allochthon, northeast Georgia: Geological Society of America Bulletin, v. 100 (in press).
Irving, E., 1979, Paleopoles and paleolatitudes of North America and speculations about displaced terrains: Canadian Journal of Earth Sciences, v. 16, p. 669–694.
Kent, D.V., and Opdyke, N.D., 1978, Paleomagnetism of the Devonian Catskill red beds: Evidence for motion of the coastal New England–Canadian Maritime region relative to cratonic North America: Journal of Geophysical Research, v. 83, p. 441–450.
—— 1980, Paleomagnetism of Siluro-Devonian rocks from eastern Maine: Canadian Journal of Earth Sciences, v. 17, p. 1653–1665.
King, P.B., and Ferguson, H.W., 1960, Geology of northeasternmost Tennessee: U.S. Geological Survey Professional Paper 311, 136 p.
Lash, G.G., and Drake, A.A., Jr., 1984, The Richmond and Greenwich slices of the Hamburg klippe in eastern Pennsylvania—Stratigraphy, sedimentology, structure and plate tectonic implications: U.S. Geological Survey Professional Paper 1312, 40 p.
Mixon, R.B., and Newell, W.L., 1977, Stafford fault system: Structures documenting Cretaceous and Tertiary deformation along the Fall Line in northeastern Virginia: Geology, v. 5, p. 437–448.
Mosher, Sharon, 1983, Kinematic history of Narragansett Basin, Massachusetts and Rhode Island: Constraints on late Paleozoic plate reconstructions: Tectonics, v. 2, p. 327–344.
Odom, A.L., and Hatcher, R.D., Jr., 1980, A characterization of faults in the Appalachian foldbelt: U.S. Nuclear Regulatory Commission NUREG/CR-1621, 314 p.
Prowell, D.C., and O'Connor, B.J., 1978, Belair fault zone: Evidence of Tertiary fault displacement in eastern Georgia: Geology, v. 6, p. 681–684.
Ratcliffe, N.M., 1980, Brittle faults (Ramapo Fault) and phyllonitic ductile shear zones in basement rocks of the Ramapo seismic zones, New York and New Jersey, and their relationship to current seismicity, *in* Manspeizer, W., ed., Field studies of New Jersey geology and guide to field trips: 52nd Annual Meeting, New York State Geological Association: Newark, New Jersey, Rutgers University, p. 278–312.
Ratcliffe, N.M., and Harwood, D.S., 1975, Blastomylonites associated with recumbent folds and overthrusts at the western edge of the Berkshire massif, Connecticut and Massachusetts—A preliminary report, *in* Harwood, D.S., ed., Tectonic studies of the Berkshire massif, western Massachusetts, Connecticut, and Vermont: U.S. Geological Survey Professional Paper 888, p. 1–20.
Reinhardt, Juergen, Prowell, D.C., Christopher, R.A., and Markewich, H.W., 1980, Evidence of Cenozoic tectonics from an isolated sedimentary basin near Warm Springs, Georgia: Geological Society of America Abstracts with Programs, v. 12, p. 508.
Rich, J.L., 1934, Mechanics of low-angle overthrust faulting as illustrated by Cumberland thrust block, Virginia, Kentucky and Tennessee: American Association of Petroleum Geologists Bulletin, v. 18, p. 1584–1694.
Richardson, R.J., Soloman, S.C., and Sleep, N.H., 1979, Tectonic stress in the plates: Reviews of Geophysics and Space Physics, v. 17, p. 981–1019.
Root, S.L., and MacLachlan, D.B., 1978, Western limit of Taconic allochthons in Pennsylvania: Geological Society of America Bulletin, v. 89, p. 1515–1528.
Roper, P.J., 1979, Evidence for post-Jurassic tectonism in eastern North America: Gulf Coast Association of Geological Societies Transactions, v. 29, p. 179–186.
Rowley, D.E., and Kidd, W.S.F., 1980, Stratigraphic relationships and detrital composition of the medial Ordovician flysch of western New England: Implications for the tectonic evolution of the Taconic orogeny: Journal of Geology, v. 89, p. 199–218.
Secor, D.T., Samson, S.L., Snoke, A.W., and Palmer, A.R., 1983, Confirmation of the Carolina slate belt as an exotic terrane: Science, v. 221, p. 649–651.
Van der Voo, R., 1983, A plate tectonics model for the Paleozoic assembly of Pangaea based on paleomagnetic data, *in* Hatcher, R.D., Jr., Williams, H., and Zietz, I., eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 19–24.
Wheeler, R.L., Winslow, Margaret, Horne, R.R., Dean, Stuart, Kulander, Byron, Drahovzal, J.A., Gold, D.P., Gilbert, O.E., Jr., Werner, Eberhard, Sites, Roy, and Perry, W.J., Jr., 1979, Cross-strike structural discontinuities in thrust belts, mostly Appalachian: Southeastern Geology, v. 20, p. 193–203.
Wickham, J.S., 1972, Structural history of a portion of the Blue Ridge, northern Virginia: Geological Society of America Bulletin, v. 83, p. 723–759.
Williams, Harold, 1978, Tectonic lithofacies map of the Appalachian orogen: St. Johns, Memorial University of Newfoundland, scale 1:1,000,000.
Williams, Harold, and Hatcher, R.D., Jr., 1983, Suspect terranes: A new look at the Appalachian orogen, *in* Hatcher, R.D., Jr., Williams, Harold, and Zietz, Isidore, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 33–54.
Wise, D.U., 1982, Linesmanship and the practice of linear geo-art: Geological Society of America Bulletin, v. 91, p. 886–888.
Wise, D.U., Dunn, D.E., Engelder, J.T., Geiser, P.A., Hatcher, R.D., Jr., Kish, S.A., Odom, A.L., and Schamel, S., 1984, Fault-related rocks: Suggestions for terminology: Geology, v. 12, p. 391–394.

ACKNOWLEDGMENTS

Supported by Nuclear Regulatory Commission Contract FIN B10538. We thank Edward O'Donnell for encouragement and helpful comments during the course of this study, and Lucian Platt, Nicholas Rast, Eldridge Moores, John Wickham, Steve Boyer, and another *Geology* reviewer for critical reviews.

Manuscript received July 2, 1986
Revised manuscript received October 19, 1987
Manuscript accepted November 3, 1987

Reviewer's comment

A well-organized and carefully prepared classification scheme that allows most faults to be placed in a single category; can aid communication between engineers, geologists, geophysicists, and public officials.

Steven Boyer