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SOFT-SEDIMENT DEFORMATION WITHIN CLASTS OF THE LIBERTY HALL FORMATION

E. Victoria Pritchard

The Middle Ordovician Liberty Hall Formation is comprised of basin and slope facies developed to the southeast of the Middle Ordovician carbonate ramp of the Appalachian basin. Near the Montgomery-Roanoke county border on the west side of Route 785, 8.7 miles (14.1 km) northeast of Blacksburg, Virginia, (Figure 1) there are excellent exposures of a portion of this formation. The locality is on the northwest limb of the southwest part of the Catawba syncline — a structure in the Pulaski overthrust sheet of the folded and thrust-faulted Valley and Ridge province.

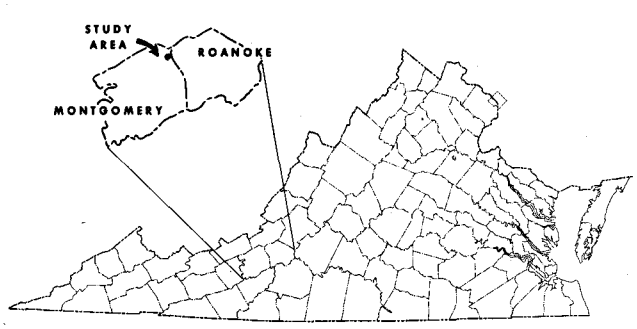

Figure 1. Index map

The Liberty Hall Formation, which ranges up to 1500 feet (450 m) thick in the Catawba syncline, overlies the Effna Limestone and locally grades laterally into biohermal and biostromal limestone buildups of the formation (Read and Tillman, 1977 and 1979). The basal 65 feet (20 m) of the Liberty Hall Formation at this locality consists mainly of interlayered dark-gray mudstone and medium-gray siltstone (Figure 2). Graptolites in the siltstone are preserved on well-developed bedding planes and the rocks show no post-depositional slump features. There is a three-foot-thick (1 m) lime mudstone exhibiting soft-sediment flowage about 55 feet (17 m) above the base of the Liberty Hall.

The siltstone is overlain by 20 feet (6 m) of non-graded, thinly bedded, dark-gray limestone with scour-and-fill structures. Directly overling this unit is a 15-foot-(4.5-m)-thick, highly folded section of

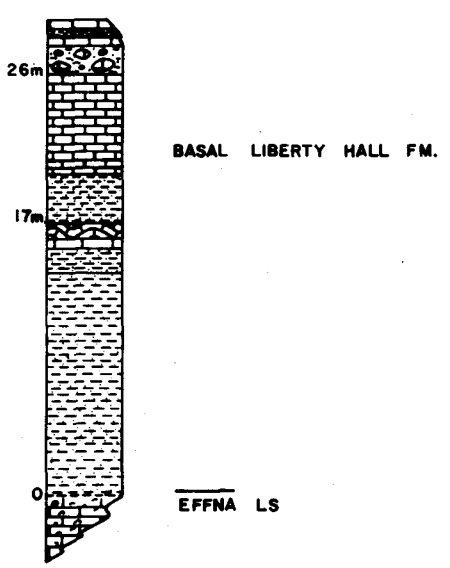

Figure 2. Section in lower part of Liberty Hall Formation.

Figure 3. Angular discordance at base of conglomerate-filled channel 85 feet (26 m) above base of Liberty Hall Formation.

dark-gray siltstone in a channel fill containing deformed cobbles. Beds in the ancient channel form a 15 degree angular discordance (Figure 3) with underlying beds. Axial surfaces of folds (Figure 4) formed in the channel deposits bear disharmonic relationships to each other.

Cobbles of dark-gray pelletal lime mudstone are enclosed in the channel fill of dark-gray, fissile, slightly pelletal siltstone (Figure 5). The cobbles, which exhibit ductile, soft-sediment deformation, are composed of dark-gray, homogeneous, pelletal

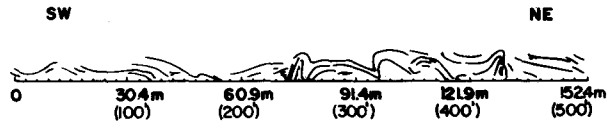

Figure 4. Sketch of disharmonic folding as seen along State Road 785 (vertical exaggeration: × 2; scale: 1 inch = 15.2 m).

lime mudstone. Interlayered light-and-dark-gray bands in the clasts result from admixtures of organic material to the clays; these bands define the deformational features observed in the cobbles.

The cobbles range in size from 1.5 to 10 inches (4 to 25 cm); shapes of the clasts range from subspherical to elongate. Degree of plastic deformation is correlated to cobble shape — sub-spherical clasts show complex responses whereas non-spherical ones exhibit little plastic deformation.

In thin sections clasts show a continuum of responses to the deforming stresses of motion. Initially, the internal layering was plastically deformed into tight "S" folds and tear-drop shapes (Figure 6). In some cases, faulting followed plastic

Figure 5. Conglomerate interval showing cobbles, which range in size from 1.6 to 10 inches (4 to 25 cm). The cobbles are enclosed in fissile siltstone.

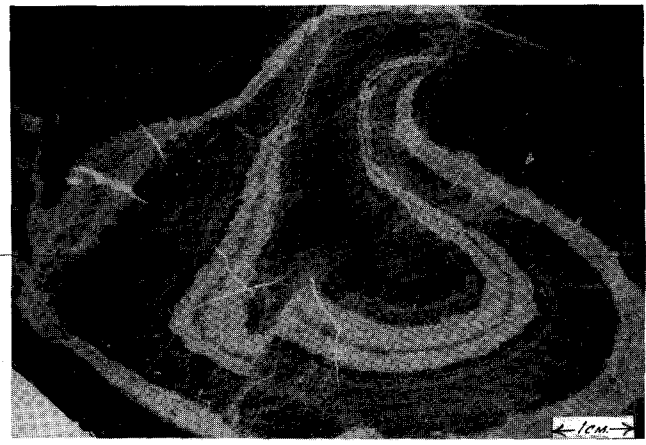

Figure 6. Interlayered bands of light- and dark-gray pelletal lime mudstone contorted into asymmetrical shapes as seen in prepared acetate peel. Bands in the lower left quadrant of photograph are offset as much as 2 mm.

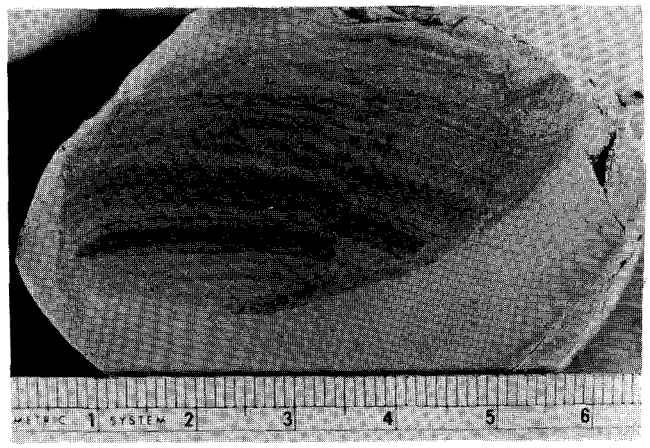

Figure 7. Faulted lime mudstone layers in sample with planar (noncontorted) layers.

deformation as continued downslope movement aided expulsion of water and extended the plastic response to the point of rupture (Figure 6). An example of brittle response is shown in Figure 7; the limestone was sufficiently cohesive to retain planar layering but ruptured during motion-induced stress.

Pelecypods of an unidentifiable species together with specimens of Cricoconarida, a class of probably pelagic Mollusca with a range from Lower Ordovician to Upper Devonian (Fisher, 1962), were found in one cobble. The assemblage, preserved undeformed, is typical of the Liberty Hall Formation.

Proposed mechanisms for triggering downslope movement include seismic shock and major storm waves (Cook and others, 1972). Although there was differential subsidence in the Catawba syncline during the Middle Ordovician (Lowry, 1974), the slumping described here may have had a different origin, movement of the muds could have been initiated because the depositional slope exceeded the angle of repose or because pore pressures sufficiently high for motion were achieved (Mountjoy and others, 1972). Instability led to the slumping of beds, as shown by the disharmonically folded zone sketched in Figure 4, and to the initiation of cobble transport, and cobble deformation. Penecontemporaneous slump features in similar facies have been reported in formations of the Middle Ordovician near Lexington and Marion, Virginia (Cooper, 1968) and near Harrisonburg, Virginia (Lowry and Cooper, 1970).

No azimuth for origin of the deformed cobbles in the Liberty Hall Formation is derivable from the observed data. They likely formed on gentle gradients on the margin of a carbonate platform of the Appalachian basin located northwest of the area. Development of the clasts is related to instabilities within the basin which culminated in failure and deformation of a discreet, 15-foot-(4.5-m-) thick sequence. The disharmonic nature of the deformed materials negates tectonism as the folding mechanism. The conglomerate clasts are probably intraformational, a conclusion supported by the observation that fossil pelagic forms typical of the Liberty Hall are in the clasts. Because the cobbles, enclosing siltstones, and immediately underlying rocks do not contain remains of benthic organisms, the beds probably do not represent a shoal provenance with good circulation. The undeformed state of the fossils in the clasts is evidence of short transportation and early lithification of the clasts.

I thank Professor W. D. Lowry for help with the field work and preparation of this paper. Professor C. G. Tillman helped in identifying fossils. George Grover, Jr., and R. Pfeil instructed me in laboratory preparation of samples and thin sections. Thanks are extended to Professor J. F. Read and to G. E. Fairbrothers who offered constructive criticism of the manuscript. Konrad Crist and Sue Bruce provided photographic help, and Gail Crum, Rita Sumas and Bernadine Harrell did the typing.

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MINERAL DEPENDENCY VERSUS MINERAL VULNERABILITY[1]

This is an audience, I know, that shares my interest in a subject that is currently getting a lot of attention — the tendency of our Nation to draw increasingly on overseas supplies of certain mineral commodities, and proportionately less on domestic sources for these minerals.

That we do obtain substantial quantities of some essential minerals from abroad is easy to demonstrate. That we will continue to do so in the foreseeable future is not in doubt. Uncertainty begins, however, when we try to interpret the significance of these facts. As with many phenomena, their meaning is open to a variety of interpretations.

The most commonly accepted interpretation is embodied in the phrase, "increasing mineral dependence." The word "dependence" has a negative connotation that is easy to grasp, and puts the trend into an uncomplicated perspective. "America's growing mineral dependence" has been the subject of articles and speeches in the minerals community for several years now, and shows signs of becoming a major policy issue of our day.

I propose today to question this interpretation of the statistics. Not to contradict it, no — the facts as I see them do not support a position as simple as that. But with responsibility for an agency whose primary concerns include discerning and interpreting mineral trends, to best promote the interests of our Nation, I feel obligated to point out that the bare concept of "America's increasing mineral dependence" is an over-simplification that leaves complex and important relationships unacknowledged — relationships that we must not lose sight of, if we wish to steer the most advantageous course for our Nation in the closing decades of the Twentieth Century.

Let me begin by tracing, to the best of my understanding, the origin of the phrase "increasing mineral dependence." The germ of this concept lay, of course, in the statistics that show America's mineral demands being met more and more by overseas sources. That trend has been underway for many years. Widespread interpretation of its true significance, however, was not attempted until the Arab oil embargo of 1973, and the subsequent OPEC price increases for petroleum. Overnight, America was shocked into the realization that self-sufficiency for a commodity of primary importance had vanished. It had not *vanished* overnight, of course; it had been leaking away for some years, and the trend was widely noted in government and industry. Widespread public appreciation of it did not come until the embargo, however, and the shock to our psyche was intense. In retrospect, it was even worse than the shock to our pocketbooks, which most of us have so far, somehow, managed to live with. But the dismay at finding out how vulnerable we were, not just to overseas shortages of a vital fuel but to overseas manipulation of supply — that dismay cut deeply, and the wound is a long way from healing. Our national self-esteem, our pride, has suffered a jolting blow.

Within the minerals community, the reaction to that revelation has been widespread, encompassing both the private and the public sectors. In part it has consisted of a search for suspected weaknesses in our resource posture — weaknesses that, if exploited by a foreign power, might expose us to the same kind of vulnerability we've experienced with respect to petroleum. Not surprisingly, evidence of some weaknesses has been found. America's heavy reliance on foreign sources for more than a score of minerals has been documented, and the case for the existence of "increasing mineral dependence" has been set forth.

I contend, however, that the case is not so simple as it has been made to appear. Dependence does not necessarily and inevitably lead to vulnerability. In the first place, petroleum is a special instance. No other mineral commodity combines the degree of universal indispensability and centralized foreign control of supplies that characterizes oil. Perhaps steel comes as close as any material to being universally necessary; we are fairly self-sufficient in iron ore, importing only about a fourth of our needs. Many of the other minerals that we require are produced by far fewer countries that export petroleum, but those minerals cannot approach petroleum in economic or industrial importance. It is hard to imagine a "bauxite embargo" or a "copper embargo" that could have anything like the impact of the oil embargo.

This puts an upper limit, therefore, on our understanding of the word "dependence" with respect to mineral resources. Whatever the situation may be, it has not yet demonstrably gone so far as vulnerability. So — how far *has* it gone?

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[1]Remarks by Lindsay D. Norman, Director, U. S. Bureau of Mines at the 83rd National Western Mining Conference in Denver, Colorado, February, 1980.

Asking that question leads us to enquire into the mechanics of our "mineral dependency." What has happened, over the past 20 years or so, to shift America's supply base from domestic to foreign sources for some minerals? Is it a simple depletion of domestic reserves, a more complicated failure of foresight and policy, or an ominous international plot?

The beginnings of an answer lie, I believe, in the most obvious fact of the post-World-War-II international economy — prosperity. Since the devastation of that war was repaired, the world in general has enjoyed an unprecedented economic boom. This is reflected in the world production figures for almost any mineral you care to name — steel, cement, copper, aluminum, and so on and on. Prosperity brought with it a healthy international expansion of production of many commodities for which a single nation, or a small group of nations, had dominated the pre-war world. Under such circumstances, it is not surprising that domestic consumers would choose to avail themselves of that expanded market, and the economies competition brings, to meet their needs.

Obviously such a situation, as described, cannot be characterized as wholly undesirable. It is clearly to the advantage of our economy for industrial consumers to be able to pick and choose among international sources of supply. From the consumers' point of view, much flexibility has been gained, and any problems that may arise with domestic sources of supply can be by-passed by switching to overseas sources — and vice versa. For the world as a whole, the situation is healthy, too. Nations are brought together in the mutual self-interest of trading partnerships, and commercial competition has the opportunity to replace more destructive international relationships.

Yet there are voices warning us against the trends inherent in these developments. From another perspective, these trends are seen to comprise our "mineral dependency," so chillingly illustrated by the example of an oil situation. From this point of view, then, we see that "dependence" is being defined as any trend that can be likened to the petroleum situation — whether or not the *degree* of dependence is as severe as in the case of oil.

It is impossible to quarrel with the concern that animates this point of view. Without a doubt, we let the oil situation get out of hand — we allowed our supply base to shift overseas and become a pawn, as it were, of international politics. We would be foolish to expose ourselves to more perils of that kind —even though they may be potentially less devastating.

The Soviet Union is often held up as an example of a nation that has thoughtfully and deliberately chosen to protect itself against such contingencies. The Soviet Union is virtually independent of imported minerals, we are reminded, at a time when the United States increases its mineral imports. This is true. A close study of how the Russians do it, however, reveals the workings of a system we have firmly rejected in most aspects. As an example, they prefer to mine ores that, by any economic test, must be called sub-marginal, if the only alternative is to import.

However attractive the advantages of such policies may seem to us at times, it is clear that no industrial democracy could afford to pursue them. Our larger self-interest forbids it. The real question is, how do we pursue that self-interest in ways that minimize our risks amidst the uncertainties of the international market? To put it another way, how do we define the word "dependency" in terms of our mineral imports?

Let us begin by re-emphasizing the distinction between "dependency" and "vulnerability." We may be "dependent" on foreign sources for twenty-five percent of our iron ore, but are we vulnerable? Probably not. It seems to me that the problem is a lot more manageable in this light. It becomes clear, in fact, that by splitting "dependency" into two more workable concepts we have identified two points on a spectrum — a range of values encompassing varying degrees of self-sufficiency and dependency. Our proper objective, then, is to determine where on that spectrum we wish to be, with respect to any given mineral.

Who makes that determination? Who gets to say "hold chromium imports at the present level," for instance, or "reduce copper imports from this country and that"? Even more important, on what basis do such decisions get made?

The answer to the first question is obvious: the Government. If the trends generated by the operation of the international market are widely agreed to be undesirable, only the Government has the authority to make the necessary changes through such mechanisms as tariffs, quotas, tax credits, and so forth. But how does the Government determine what to do, and when?

That process always has involved and doubtless always will involve contributions from many different areas of expertise. But, there is in Government today a new awareness of the complexity of our mineral supply problems, and a new consciousness of the need for an enhanced mineral expertise in developing workable approaches to them. In fact, the Bureau of Mines has just reorganized itself around the concept of becoming the Federal Govern-

ment's central agency for mineral problem and mineral policy analysis. Long a major source of minerals research and statistics, we are logically extending our mandate to permit an informed analysis of mineral trends, and of the probable results of policy alternatives suggested for Federal implementation. I would like to spend my remaining few minutes in describing the Bureau's new role, and its impact on the "mineral dependency/-vulnerability" issue.

To begin with, the issue cannot be seriously studied without breaking it into its logical components — that is, we must examine the individual mineral commodities one by one. This goes further than merely collecting and publishing the statistics on each, and the Bureau's new Minerals Availability System, or MAS, is designed to be the next step forward. The system aims at assessing the worldwide availability of nonfuel minerals, and its foundation is an ever-enlarging computerized data bank containing information on the world's minerals, deposit by deposit.

Our newly published report, "Copper Availability — Domestic," will serve as an illustration of how MAS works. (Copper was selected as one of the first commodities for study, not because it represents a vulnerability prospect but because it exemplifies many of the problems with which our domestic mineral industries must contend.) From the computer we extracted grade, reserve, and other ore data on the 73 key domestic copper deposits — the major deposits, producing or not, that have demonstrated reserves or resources. Then, for each of the deposits, we developed a detailed estimate of the costs of mining and milling the ore.

Capital expenditures and operating costs were estimated for every step from exploration through the concentration process. This permitted a financial evaluation of each property, and the final product then emerged: a tonnage-price relationship showing how much domestic copper would be available over a range of prices at varying rates of return.

The value of such a study, in any informed analysis of America's copper postion, is apparent. The study makes it possible to give quantitative answers to "what-would-happen-if" questions, expressed in terms of price changes, and it can be a building block for further analysis. This is the kind of ground-breaking work that must and *will* be done to approach the "mineral dependency" issue on a firm footing of fact.

The next step in such an approach will be taken by our Analysis group, which will use the MAS copper study in the construction of "scenarios" for possible future developments. Only from such analyses can really clear definitions of "dependency" and "vulnerability" emerge. As you can see, many factors might enter into the definition, including the domestic reserve base for the mineral under consideration, the effect or price changes on that base, the domestic labor supply, the history of output in a given foreign country and the factors that influence it, the diversity of foreign sources, and so forth.

Such analysis is valuable not only for the additional insights it provides policymakers, but also for the help it gives to the Bureau's own planners in programming research. Through research we can try to change an important term of the "vulnerability equation" — the term that stands for current technology. And a better understanding of where dependency ends and vulnerability begins with respect to specific commodities enables us to allocate our research resources as efficiently as possible.

Extensive analysis isn't always needed, of course. We already know, for example, that domestic bauxite production is a fraction of domestic demand, and that one source accounts for half our imports. In such a situation, one can readily glimpse the *prospect* of vulnerability. And minimizing such prospects is an important objective of Bureau research.

Consequently, we have research underway that is exploring non-bauxite sources of alumina. Such sources are abundant, of course, but the technology for recovering them has not been economic. A few years ago, the Bureau evaluated the non-bauxitic sources, and the applicable extraction methods, and set up a "mini-plant" to test the most promising combinations. In the end, we identified a hydrochloric acid process, using clay for a raw material, as the best possibility, and plans for a pilot plant to test and refine the process have been drawn up. We don't anticipate, of course, that successful tests will eliminate bauxite imports and start a whole new American mining industry; such expectations would be unrealistic. Within the bounds of our dependency on foreign bauxite, however, we are entitled to a "fall-back position" — a domestic line of defense against potential interruptions of bauxite shipments, or unwarranted price increases; in short, a defense against vulnerability.

In a similar endeavor, the Bureau is working on a process that could make domestic supplies of cobalt, nickel, and chromium available from the lateritic ores of the Oregon-California border region. Although the potential addition to supply would offset only a small portion of current imports, the process does appear to have economic potential.

At this point it is appropriate, I think, to consider one of the issues that is uppermost in the industry's mind, whenever the subject of increasing imports

comes up. That issue is regulation, chiefly environmental and health and safety regulation. The increasing costs of regulation are said to be a significant factor in shifting supply from domestic to foreign sources. The Bureau of Mines has two concerns here. First, we want to develop the ability to show with some precision what the impact of new regulations would be on the mineral industry both in dollars and in output. Such precision, which no one has yet been able to achieve, should go a long way toward settling the often-fruitless debates over regulatory proposals. Second, the Bureau's environmental research program is aimed at providing a sound technological basis for new regulation. I don't think anyone would deny that, in some instances, intense and genuine concern over pollution and occupational hazards has led to the formulation of regulations that just couldn't be met with available technology. We are determined to minimize such occurrences in the future.

These are only a few examples of what the Bureau of Mines is doing. It is clear to me, however, that we are not doing enough. The job is so important, and has been so inadequately defined up to now, that much remains to be done.

First of all, the data analysis and policy evaluation function must be nurtured carefully to reach its full growth. We are building our capabilities deliberately, step by substantial step, to get a program that can stand on its own. We will be working to strengthen this program significantly in the years ahead. I believe it represents a really important extension of traditional Bureau efforts in mineral economics.

Next, the Bureau of Mines can and must do more in research. Our recent reorganization, aimed in part at streamlining the research effort, will greatly facilitate an expanded search for more domestic sources of important minerals that we import in large quantities. Of course, our research will become a more effective tool as it comes under the increasing guidance of our mineral analysis program, which will be able to "pinpoint" promising research targets with far greater accuracy.

The United States is a great country. We are even stronger and more resilient than we might have believed ourselves to be, ten years ago. We have absorbed the shock of an oil embargo, and subsequent price increases, but not without major inflationary impacts. To avoid additional ones, we must find intelligent ways to protect ourselves. And there is every reason to believe that intelligently conceived protective measures will succeed. All we really need, in my opinion, is the will to commit our resources to the work, and the self-confidence to keep us on the chosen course without faltering.

SUMMER CREDITED ENVIRONMENTAL EDUCATION COURSES

For the twenty-fifth year the Environmental Education Courses will be held at Virginia colleges. These three week summer courses in June and July are designed to acquaint teachers and others to become better acquainted with Virginia's mineral resources, wildlife, forests, soil and water and marine life.

Courses are offered for credit at Virginia Tech, William & Mary, Virginia State, and Longwood. Specialists from the various disciplines offer their time as instructors. Full and partial scholarships are given. By means of classroom discussion and field trips information is given which can assist in making decisions about resource and environmental management. Since these courses began some 2000 teachers and through them 250,000 students have been exposed to a better appreciation of natural resources. The scholarships are supported by contributions from industry, soil and water conservation districts, and various recreational clubs.

Information on scholarships can be obtained from: Virginia Resource Use Education Council, c/o Bernard L. Parsons, VPI & SU, Seitz Hall, Blacksburg, VA 24061. Those submitting applications early stand the best chance of getting scholarships at the institution of their choice.

SCHEDULED MEETINGS

February 22-27 American Society of Photogrammetry - American Congress on Surveying and Mapping at Washington Hilton Hotel, Washington, D. C.

March 19, 20 Southeastern Section, Geological Society of America in Hattiesburg, Mississippi (Daniel A. Sundeen, Dept. of Geology, University of Southern Mississippi, Box 8196, Southern Station, Hattiesburg, MS 39401).

April 9-11 Northeastern Section, Geological Society of America in Bangor, Maine (Arthur M. Hussey, Dept. of Geology, Bowdoin College, Brunswick, Maine 04011).

May 14, 15 Virginia Academy of Science (Geology Section) at Old Dominion University, Norfolk.

June 5-7 Eastern Section, National Association of Geology Teachers, in Brockport, N. Y. (Richard M. Liebe, Dept. Earth Sciences, SUNY, Brockport, N. Y. 14420).

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Geologic Structure and Hydrocarbon Potential along the Saltville and Pulaski Thrusts in Southwestern Virginia and Northeastern Tennessee by M. J. Bartholomew and others. This publication consists of six sheets which show rock character and deformation in parts of Montgomery County, Virginia and Hawkins County, Tennessee by means of interpretive cross-sections, photographs, geologic maps, and a road log. The locations of oil and gas fields in southwestern Virginia are shown. Information is listed for significant exploratory test and natural gas potential is discussed, $10.50*.

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Geology of the Willis Mountain Quadrangle by John D. Marr, Jr. One 36 x 48 inch sheet in color with sections on economic geology by Palmer C. Sweet and Triassic Geology by Michael B. McCollum, $4.50*.

PUBLICATION 26

Geology of the Andersonville Quadrangle by John D. Marr, Jr. One 36 x 48 inch sheet in color with a section on economic geology by Palmer C. Sweet, $4.50*.

SPECIAL PUBLICATION

Directory of Geologists Employed in Virginia (exclusive of U. S. Geological Survey, Reston) by H. W. Webb, Jr., 22 p., 1980 - $1.50*.

Listings included are: geologists' names; organization addresses and geologists' job titles; and organization names. Both mailing addresses and phone numbers of place of employment are indicated.

*For publications mailed to Virginia addresses, add 4 percent State sales tax.