MINERAL RESOURCE PROVINCES OF VERMONT

A current look at Vermont's mineral resources potential and mineral industries.

February 1982

by

Charles A. Ratte'

State Geologist

Vermont Geological Survey, DEC
103 South Main St, Laundry Building
Waterbury, VT 05671-0301

Open-File Report #1982-1

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THE CARBONATE PROVINCE

MARBLE

Vermont's dimension stone marble is known the world over. The Danby Imperial white marble, the Isle La Motte black marble (limestone) and the green Verde Antique (serpentinite) are among the industries most noted products. The Verde Antique has been discussed under the ultramafic province since it is truly a product related to ultramafic geology and not carbonate geology. The major operator of Vermont's marble industry is the Swiss firm OMYA, Inc., a Pluess-Staufer Company.

In addition to dimension stone, the Vermont marble industry supplies an increased international demand for a finely-ground calcium carbonate product. Quarries at East Middlebury and Wallingford supply the White Pigment Co. mills at New Haven Junction and Florence, and the Smokerise quarry at Brandon supplies the Vermarco Company mill at Florence. The OMYA, Inc. mill at Florence is also supplied by the white marble quarry at East Middlebury.

The most sought after marble for both the dimension stone and ground products industries are the white marbles. The Columbian member of the Ordovician Shelburne Formation where thickened by folding or faulting has proven to be the most successful geologic target for the industry. The quarries listed above are located in this stratigraphic-structural setting. The Shelburne Formation is shown on the state geologic map (Doll, 1961) in the Champlain and Vermont Valleys from Colchester to Bennington. Minor production has come from the Upper Cambrian Sutherland Falls member of the Clarendon Springs Formation, and from the Lower Ordovician Bascom Formation.

The fossiliferous Crown Point member of the Middlebury Formation harbors the one black marble (limestone) quarry used for dimension stone. The quarry is located on Isle La Motte in Grand Isle County. It was last worked in the late 1960's-early 1970's. This limestone abounds in fossil remains of Ordovician gastropods, Maclurites magnus and Raphistoma striatum.

The Danby Imperial quarry located on the northeast flank of Dorset Mountain in Danby, Vermont is perhaps the world's largest operating underground marble quarry. Stone from this quarry also is located in the Columbian white marble of the Ordovician Shelburne Formation.

The Smokerise quarry at Brandon commenced operation on December 13, 1979 and is the first new quarry to come on line since 1964. Rock from this quarry is supplying the mills at Florence, once supplied by the Loveland quarry which was depleted in 1979. Several former dimension stone quarries

are currently being considered for re-activation to supply the ground products mills.

LIMESTONE

With the exception of the black limestone quarry on Isle La Motte which supplies the dimension stone industry, all other limestone quarries produce crushed stone for a variety of uses. The primary use is for road base and bituminous concrete aggregate for highway construction. Both permanent quarries and small single-contract rock-borrow quarries exist throughout the (marble-limestone) Carbonate Province.

The permanent quarries are located in Swanton (The Swanton-Shelburne Limestone Corp.), Winooski (Frank W. Whitcomb Construction Corp.), Shelburne (The Swanton-Shelburne Limestone Corp.) and New Haven (Pike Industries Inc.). The marble companies discussed above also produce crushed stone for aggregate, agricultural lime and other uses.

Several formations with dominantly carbonate lithologies are exploited by the crushed stone industry. The Beldons member of the Ordovician Chipman Formation is quarried at Swanton and New Haven, the Ordovician Shelburne Formation provides the rock for the Shelburne Limestone Corp. quarry at Shelburne, and the Cambrian Winooski Formation is quarried in Winooski by Whitcomb. These formations are present as disconnected belts throughout the Carbonate Province.

The northwestern margin of the Carbonate Province is in New York state and does not show on the mineral resource map of Vermont (see Plate I). This margin extends from Champlain (New York) through Chazy (New York), to Ticonderoga (New York) and back into Vermont at Chipman Point.

Crystalline limestones associated with the Devonian Waits River Formation in eastern Vermont, and carbonate lenses of limited occurrence in other formations (Pinney Hollow, Underhill) have been quarried in the past but offer no significant resource.

MARBLE

Adams, C. B., 1845, First annual report on the geology of Vermont: Burlington, VT, Chauncey Goodrich, 92 p., SGL, VSL.

American Verde Antique Marble Company, 1853, Survey of quarries: Private publication, 8 p., VHL, VSL.

Bain, G. W., 1931, Flowage folding: Am. J. Sci., 5th series, v. 22 p. 503-530.

Bain, G. W., 1933, The Vermont Marble belt: Guidebook 1, Eastern New York and Western New England, 16th Intercollegiate Geological Conference., p. 75-80.

Bain, G. W., 1934, Calcite marble: Economic Geology, v. 29, no. 2, p. 1210139.

Bain, G. W., 1936, Serpentinization of Vermont ultrabasics: Geological Society of America, Bulletin, v. 47, no. 12, p. 1961-1979, SGL.

Bain, G. W., 1938, Central Vermont marble belt (abs.): Geological Society of America, Bulletin, v. 49, no. 12, part 2, p. 1863-1864.

Bain, G. W., 1938, Central Vermont marble belt: Guidebook, New England Intercollegiate Conference., 34th Annual Mtg., 31 p.

Bain, G. W., 1959, Geology of the marble deposits near Rutland, Vermont: Zen, E-an, ed., Guidebook, New England Intercollegiate Geological Conference, 51st Annual Meeting., p. 35-42, SGL.

Bosworth, W., 1977, Structural petrology of a mixed phyllite-marble terrane, Pownal, Vermont: Unpublished Master's thesis, Rensselaer Polytechnic Institute, Troy, NY, 152 p.

Brainerd, Ezra, 1885, The geological features of the marble belt of western New England: Middlebury Hist. Soc., Papers and Proc., v. 1, part 2, p. 9-21.

Bristol, W. A., 1912, High tension testing of Vermont slate and marble: Vermont State Geologist, 8th Report (1911-1912), p. 196-219, SGL, VSL.

Busenberg, Eurybiades, 1967, Investigation of blistering phenomena in serpentinite (verde antique) from Rochester, Vermont: Unpublished Master's thesis, New York University, New York, NY, 32 p.

Chidester, A. H., 1959, Steatitization of serpentinite bodies in north-central Vermont: Unpublished Ph.D. thesis, University of Chicago, Chicago, IL.

Dale, T. N., 1912, The commercial marbles of western Vermont: U. S. Geological Survey, Bulletin, no. 521, 170 p.

Dale, T. N., 1914, The calcite marble and dolomite of eastern Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 224-276, SGL, VSL.

Dale, T. N., 1914, The commercial marbles of western Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 1-160, SGL, VSL.

Dale, T. N., 1915, The calcite marble and dolomite of eastern Vermont: U. S. Geological Survey, Bulletin, no. 589, 67 p.

con't

Dana, J. D., 1882, On the crystalline limestone and the conformably associated Taconic and other schists of the Green Mountain region: Collection of papers appearing in the American Journal of Science, New Haven, CT.

Doll, C. G., 1962, Report of the State Geologist: For the biennium, July 1, 1960-June 30, 1962, 13 p., SGL.

Doll, C. G., 1964, Report of the State Geologist: For the biennium, July 1, 1962-June 30, 1964, 17 p., SGL.

Doll, C. G., 1966, Report of the State Geologist: For the biennium, July 1, 1964-June 30, 1966, 14 p., SGL.

Doll, C. G., 1968, Report of the State Geologist: For the biennium, July 1, 1966-June 30, 1968, 19 p., SGL.

Doll, C. G., 1970, Report of the State Geologist: For the biennium, July 1, 1968-June 30, 1970, 23 p., SGL.

Doll, C. G., 1972, Report of the State Geologist: For the biennium, July 1, 1970-June 30, 1972, 24 p., SGL.

Doll, C. G., 1974, Report of the State Geologist: For the biennium, July 1, 1972-June 30, 1974, 24 p., SGL.

DuClos, K. F. and Thresher, M. C., ed., 1976, The history of Braintree, Vermont, v. II, 1883-1975: Montpelier, VT, Capital City Press, p. 47-50, SGL.

Elliott, A. H., 1885, The colored marbles of Lake Champlain (with Discussion by J. S. Newberry): N. Y. Acad. Sci., Trans., v. 3, p. 100-102.

Erwin, R. B., 1957, The geology of the limestone of Isle LaMotte and South Hero Island, Vermont: Vt. Geological Survey, Bulletin, no. 9, 94 p., SGL, VSL.

Faill, R. T., 1969, The effect of loading rate in the experimental deformation of a limestone (abs.): Dissertation Abstracts International, v. 30, no. 4, p. 1752B.

Forrest, J. T., 1967, Environment of deposition of the Orwell limestone: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 58 p.

Gale, D. C., 1914, A marble city and a marble village: New England Magazine, p. 195-200, VHL.

Gale, D. C., 1922, Rise of the Vermont Marble Company: Proctor, the story of a marble town, Brattleboro, VT, Vermont Printing Co., chapter 5, p. 95-144.

Gavish, Eliezer and Reynolds, R. C., 1970, Structural changes and isomorphic substitution in illites from limestones of variable degrees of metamorphism: Israel Journal of Chemistry, v. 8, no. 3, p. 477-485.

Hager, A. D., 1858, The marbles of Vermont: Vermont Historical Society, Proceedings, 16 p., VSL.

Hayes, A. A., 1855, On the so-called verde antique marble from Roxbury, Vermont: Boston Society of Natural History, Proceedings, v. 5, p. 260-263, p. 339-341.

Hayes, A. A., 1856, On serpentine rock: American Journal of Science, 2nd series, v. 21, no. 63, p. 382-385, VHL.

con't

Hitchcock, C. H., 1867, The Winooski marble of Colchester, Vermont: Boston Society of Natural History, Proceedings, v. 16, p. 119.

Jackson, C. T., 1856, Chemical analysis and comparison of serpentine marbles known under the name of verde antique: Boston Society of Natural History, Proceedings, v. 5, p. 314-318, p. 3410343, also American Journal of Science, 2nd series, v. 23, p. 123-126, also Mining Magazine, v. 6, p. 410-413.

Jacobs, E. C., 1918, The lime industry in Vermont: Vermont State Geologist, 11th Report (1917-1918), p. 158-164, SGL, VSL.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Jenks, M. B., 1932, Marble quarrying in Vermont: Unpublished Master's thesis, University of Vermont, Burlington, VT, 81 p.

Jones, E. H., 1968, Marble under the mountains: Vermont Life, v. 22, no. 3, p. 207, VHL, VSL.

Kent, D. F., 1942, The areal and structural geology of the north end of the Vermont marble valley: Unpublished Master's thesis, Northwestern University, Chicago, IL, 75 p.

Newberry, J. S., 1870, Marble beds of Vermont: Troy Lyceum Nat. Hist., Proc., v. 1, p. 62-63.

Perkins, G. H., 1883, The Winooski marble of Vermont (abs.): American Association for the Advancement of Science, Proceedings, v. 31, p. 388.

Perkins, G. H., 1885, The Winooski or Wakefield marble of Vermont: American Naturalist, v. 19, p. 128-136.

Perkins, G. H., 1898, Report of the marble, slate, and granite industries of Vermont: Rutland, VT, The Tuttle Company, 68 p., VSL.

Perkins, G. H., 1900, Report of the State Geologist on the mineral resources of Vermont (1899-1900): Burlington, VT, Free Press Assoc., 83 p., VSL.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1914, History of the marble industry in Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 161-223, SGL, VSL.

con't

Perkins, G. H., 1914, The mineral resources of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 430-439, SGL, VSL.

Perkins, G. H., 1916, Mineral resources of Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 293-298, SGL, VSL.

Perkins, G. H., 1918, Mineral resources of Vermont: Vermont State Geologist, 11th Report (1917-1918), p. 204-208, SGL, VSL.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Perkins, G. H., 1924, Mineral resources of Vermont: Vermont State Geologist, 14th Report (1923-1924), p. 344-351, SGL, VSL.

Perkins, G. H., 1925, Mineral resources of Vermont: Vermont State Geologist, 15th Report (1925-1926), p. 264-271, SGL, VSL.

Perkins, G. H., 1929, Mineral resources of Vermont: Vermont State Geologist, 16th Report (1927-1928), p. 382-386, SGL, VSL.

Perkins, G. H., 1930, Mineral resources of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 253-259, SGL, VSL.

Perkins, G. H., 1932, The marble industy of Vermont: Vermont State Geologist, 18th Report (1931-1932), p. 1-315, SGL, VSL.

Ries, Heinrich, 1896, The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut: U. S. Geological Survey, Annual Report, No. 17, part 3, p. 795-811.

Seely, H. M., 1885, The marble fields and marble industry of western New England: Middlebury Hist. Soc., Papers and Proc., v. 1, part 2, p. 23-52.

Sheppard, S. M. F. and Schwarcz, H. P., 1966, Isotopic studies and the size of partial equilibrium systems in marbles (abs.): American Geophysical Union, Transactions, v. 47, no. 1, p. 213.

Silliman, Benjamin, 1839, Marble and serpentine in Vermont: American Journal of Science, v. 35, p. 390.

Smith, H. L., 1916, The lime plant of the Vermont Marble Company: Vermont State Geologist, 10th Report (1915-1916), p. 101-110, SGL, VSL.

Swift, Samuel, 1859, Addison County--Territory, face of the county, soil, original forests, lime, marble, streams: History of the town of Middlebury in the County of Addison, Vermont, a statistical and historical account of the county; Middlebury, VT, A. H. Copeland, p. 5-18, VSL.

Vermont Life, 1948, Vermont marble: v. 2, no. 4, p. 34-41, VHL, VSL.

Vermont Marble Company, no date, The book of Vermont marbles; a reference book for the architectural profession: Cambridge, MA, Barta Press, 2nd ed., 69 p.

con't

MARBLE SUPPLEMENT

Barton, W. R. and Ratte', C. A., 1976, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 7 p., SGL.

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Bitar, R. F. and Armstrong, M. K., 1982, Mineral resources of Bread Loaf RARE II further planning area, Addison and Washington Counties, Vermont: U. S. Department o the Interior, Bureau of Mines, Open-File Rept., MLA-65-82, 15 p., SGL.

Doll, C. G., 1956, Report of the State Geologist and Vermont Geological Survey: For the biennium, July 1, 1954-June 30, 1956, 8 p., SGL.

Meade, L. P., 1980, The Vermont marble belt and the economics of current operations: Dunn, J. R., et al., eds., Proceedings from the 14th annual forum on the geology of industrial minerals, theme II, Industrial mineral mining in complex geologic regions, N. Y. State Museum, Bulletin, no. 436, p. 54-56, SGL.

Middlebury Historical Society, 1885, The marble border of western New England: Middlebury Historical Society, v. 1, part 2, 63 p., VSL.

Odgen, D. G., 1967, Considerations of structural geology in the search for white, high-calcium marble as a source of industrial fillers: Farquhar, O. C., ed., Economic geology in Massachusetts, Pub., University of Massachusetts Graduate School, Amherst, MA, p. 181-184, SGL.

Ratcliffe, N. M., 1979, Adoption and redefinition of the Sherman marble and regional correlations of Plymouth-type and Sherman-type marbles in Vermont and Massachusetts: Sohl, N. F. and Wright, W. B., authors, Changes in stratigraphic nomenclature by the U. S. Geol. Surv., Bull., no. 1482-A, p. 79-86.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vt. Div. Geol. and Earth Res., Open-File Rept., no. 1982-1, scale 1:250,000, SGL.

White, D. H., Jr. and Ratte', C. A., 1979, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, 1978-1979, v. 2, 7 p., SGL.

SGL--Available from the State Geologist's Library, State Geologist's Office, Montpelier,
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

LIME -- LIMESTONE

Dale, T. N., 1914, The calcite, marble, and dolomite of eastern Vermont: Vermont State Geol. Rept. No. 9, 1913-1914, p. 224-276.

Dale, T. N., 1915, The calcite, marble, and dolomite of eastern Vermont, U. S. Geol. Survey Bull. 589, 67 p.

Erwin, R. B., 1957, The geology of the limestone of Isle La Motte and South Hero Island: Vermont Geol. Survey Bull. No. 9, 94 p.

Forrest, J. T., 1967, Environment of deposition of the Orwell limestone: Thesis, Middlebury College.

Jacobs, E. C., 1918, The lime industry in Vermont: Vermont State Geol. Rept. No. 11, p. 158-164.

Jacobs, E. C., 1934, Lime: Vermont State Geol. Rept. No. 19, p. 29-30.

Ries, H., 1896, The limestone quarries of eastern New York, western Vermont, Mass., and Connecticut: U. S. Geol. Survey, Annual Report No. 17, part 3, p. 795-811.

Smith, H. L., 1916, The lime plant of the Vermont Marble Company: Vermont State Geol. Rept. No. 10, p. 101-110.

THE GRANITIC PROVINCE

Granitic plutons assigned to the Devonian New Hampshire Pluton Series are known to exist the entire length of the state from the Black Mountain pluton in Dummerston to the large pluton of Averill Granite in Norton and Averill in northeastern Vermont. Although granite has been quarried in nearly all these plutons at one time, the most active quarries today are in the Barre pluton at Graniteville and Websterville. The dominant exposures of granitic rock of the New Hampshire Series lie north and east of Barre. This region can be designated as Vermont's Granitic Province and it is here that future exploitation will most likely occur.

Barre Granite: Barre granite is the name given to the medium-textured uniformly gray colored granodiorite. It was mapped and described by Murthy(1957). Two quarry companies operate five quarries in the Graniteville-Websterville mining district which is approximately three miles southeast of the town of Barre (pronounced like "berry"). The Rock of Ages Corp. operates the Wetmore-Morse, Smith, Rock-of-Ages, and Pirie quarries, and the Wells-Lamson Quarry Co. operates their Wells-Lamson quarry at Websterville.

Woodbury Granite: The Woodbury Granite mapped and described by Konig(1961) is found in several small exposures in the towns of Woodbury and Hardwick. The Woodbury granite is light to medium gray, generally with medium-textured grains, however grain size and texture vary in the several exposures in the region. Quarries east and northeast of the town of Woodbury once supplied a very prosperous granite industry in Hardwick. The center of the industry has since shifted to the Barre area and only one operator, John Swenson Granite Co. (Concord, N.H.), is currently quarrying the Woodbury granite.

Adamant Granite: The Adamant granite mapped and described by Cady (1956) and Konig (1961) occurs as sills trending northeasterly in the village of Adamant (Calais township). This granite is a mottled gray varying in texture from medium-coarse equigranular in the thicker sills to porphyritic in the thin sills. Until recently the Garand Teed Quarries, Inc. produced rough blocks from a quarry in one of the thicker sills of Adamant granite. The present owner does not anticipate further commerical use of the Adamant quarries.

Derby Granite: The Derby granite (not officially named) has been mapped and described by Doll (1951). It occurs in several large plutons exposed in the towns of Derby, Charleston, Barton, Irasburg and Westmore. The granite is light to dark gray, medium to coarse grained and varies from equigranular to porphyritic texture. The old Willey Granite Quarry northwest of Derby Center is currently operated by Granite Hills, Inc. providing rough granite blocks for the Rock of Ages Corp.

COLORED GRANITES

Bethel White Granite: The Bethel granite was mapped and described by Ern (1963). One small exposure of this granite is located on Quarry Hill northeast of the village of Bethel. A large quarry which provided highway aggregate for construction of Interstate 89 can be seen just west of this highway approximately two miles north of Interchange #3. The Rock of Ages dimension stone quarry is a short distance west of this site.

The rock is medium to coarse grained and nearly pure white. It is composed almost entirely of leucocratic minerals quartz, oligoclase, orthoclase, microcline and muscovite. Minor quantities of biotite and epidote provide cloudy, dark splotches in the rock. The rock has been classed as a quartz monzonite (Ern, 1963).

Braintree Granite: The Braintree granite was also mapped and described by Ern (1963). This pluton is located west of the village of East Braintree and like the Bethel White granite pluton lies to the south of the main granitic province. This granite, where quarried has a medium gray color with a faint pinkish tint. It is a medium to coarse textured, equigranular rock. The pluton is also composed of a dioritic phase that makes up the western half of the Braintree pluton. Mr. John Murray of Randolph actively quarried the rock for personal use only. The quarry property is currently owned by Mr. Murray.

Extensive exploration in Vermont seems unwarranted. The various occurrences of granitic rocks are well known. There is an interest in locating colored varieties of igneous rock suitable for monumental and dimension stone. Known occurrences of unaltered, medium to coarse grained, mafic igneous rocks are few and the expectations of finding large plutons of such rocks in Vermont are minimal. Rock within the boundaries of current mining districts is apparently ample for foreseeable needs. Numerous abandoned granite quarries exist throughout the granitic province and in other small granitic plutons outside the province. These quarries have exploited rock of Precambrain age in a small granitic body west of Tyson, Vermont, and Mesozoic granitic rocks at Mount Ascutney in Brownsville (West Windsor).

Baldwin, Brewster, 1961, The Barre granite quarries: Doll, C. G., ed., Guidebook, New England Intercollegiate Geological Conference, 53rd Annual Meeting, section 4, trip B-2, 6 p.

Beaulieu, G. M., 1981, Oxygen isotopic geochemistry, major element chemistry, and petrography of the Devonian New Hampshire magma series of northeastern Vermont: Unpublished Masters thesis, University of Georgia, Athens, GA, 88 p., SGL.

Belding, Patricia, 1974, The ceaseless quarries of Barre, Vermont: Vermont Life, v. 29, no. 2, p. 19-23, VHL, VSL.

Bowles, Oliver and Hatmaker, P., 1931, Trends in the production and use of granite as dimension stone: U. S. Bureau of Mines, Report of Investigations, no. 3065, 21 p.

Bowman, J. R., 1974, Gravity anomalies in west-central Vermont: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 37 p.

Bullaty, Sonja and Lomeo, Angelo, 1957, Quarry patterns: Vermont Life, v. 11, no. 4, p. 2-7, VHL, VSL.

Dale, T. N., 1907, Recent work on New England granites: U. S. Geological Survey, Bulletin, no. 315, p. 356-359, VSL.

Dale, T. N., 1908, The granites of Vermont: Vermont State Geologist, 6th Report (1907-1908), p. 58-75, SGL, VSL.

Dale, T. N., 1909, The granites of Vermont: U. S. Geological Survey, Bulletin, no. 404, 138 p.

Dale, T. N., 1910, The granites of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 78-197, SGL, VSL.

Dale, T. N., 1923, The commercial granites of New England: U. S. Geological Survey, Bulletin, no. 738, 488 p.

DeKroutschoff, K., 1885, Note sur le granite variolitique de Craftsbury en Amerique: Societe Geologique de France, Bulletin, v. 8, p. 132-141.

DeKroutschoff, K., 1885, Note sur le granite variolitique de Craftsbury en Amerique: American Naturalist, v. 20, p. 275-276.

Doll, C. G., 1951, Geology of the Memphremagog quadrangle and southeastern portion of the Irasburg quadrangle, Vermont: Vt. Geol. Surv., Bull., no. 3, p. 41-49, p. 77, SGL, VSL.

Douglass, P. M. and Voight, Barry, 1969, Anisotrophy of granites--A reflection of microscopic fabric: Geotechnique, v. 19, no. 3, p. 376-398.

DuClos, K. F. and Thresher, M. C., ed., 1976, The history of Braintree, Vermont, v. II, 1883-1975: Montpelier, VT, Capital City Press, p. 47-50, SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

con't

Engelder, Terry, Sbar, M. L., and Kranz, R. L., 1977, A mechanism for strain relaxation of Barre granite--Opening of microfractures: Pure and Applied Geophysics, v. 115, no.s. 1-2, p. 27-40, also Lamont-Doherty Geological Observatory, contribution no. 2455.

Eric, J. H. and J. G. Dennis, 1958, Geology of the Concord-Waterford area, Vermont. Vt. Geol. Surv., Bull., no. 11, p. 25-28, p. 61-62, SGL, VSL.

Ern, E. H., Jr., 1963, Bedrock geology of the Randolph quadrangle, Vermont: Vt. Geol. Surv., Bull., no. 21, p. 75-84, p. 90-92, SGL, VSL.

Finlay, G. I., 1901, The granite of Barre, Vermont (abs.): Science, n.s., v. 13, p. 509, also N. Y. Academy of Science, Annual Report, no. 14, p. 101-102.

Finlay, G. I., 1902, The granite area of Barre, Vermont: Vermont State Geologist, 3rd Report (1901-1902), p. 46-60, SGL, VSL.

Foland, K. A., Srogi, E. L., and Friedman, I., et al, 1979, Petrogenetic relations at the Mount Ascutney Complex, Vermont, based upon chemical and Sr and O isotopic study (abs.): Geol. Soc. Am., 92nd Annual Mtg., Abs. with Prog., v. 11, no. 7, p. 427.

Foland, K. A., Srogi, E. L., and Henderson, C. M. B., 1980, Chemical and isotopic consequences of the incorporation of xenoliths by syenite at Ascutney Mountain, Vermont (abs.): Geol. Soc. Am., Northeastern Section, 15th Annual Mtg., Abs. with Prog., v. 12, no. 2, p. 36.

Goodwin, B. K., 1963, Geology of the Island Pond area, Vermont: Vt. Geol. Surv., Bull., no. 20, p. 41-65, p. 107, SGL, VSL.

Goodyear, F. A., 1952, Petrographic study of the Murray-Goodbill granite (Braintree Hill, Vermont): Unpublished report, University of Vermont, Burlington, VT, 8 p., SGL.

Hoffman, P. A., 1974, The Braintree granite--A study of the petrology and conditions of emplacement of the Braintree granite: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 41 p., SGL.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Jahns, R. H., 1953, Rock bursting and other geologic problems in the granite quarries at Barre, Vermont (abs.): Economic Geology, v. 48 no. 4, p. 328.

Konig, R. H., 1961, Geology of the Plainfield quadrangle, Vermont: Vt. Geol. Surv., Bull, no. 16, p. 45-58, p. 83-84, SGL, VSL.

Konig, R. H. and Dennis, J. G., 1964, The geology of the Hardwick area, Vermont: Vt. Geol. Surv., Bull., no. 24, p. 27-34, SGL, VSL.

Leland, E. S., 1947, Barre: Cosmopolitan city and granite center of the world: Vermont Life, v. 2, no. 1, p. 24-29, VHL, VSL.

McCormick, Calvin, 1886, The inclusions in the granite of Craftsbury, Vermont: American Association for the Advancement of Science, Proceedings, v. 37, p. 19-24.

Meyers, P. B., Jr., 1964, Geology of the Vermont portion of the Averill quadrangle, Vermont: Vt. Geol. Surv., Bull., no. 27, p. 28-49, p. 64-65, SGL, VSL.

Mihalik, Mary Ann, 1976, The origin of the Plymouth granite: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 66 p.

Morse, D. A., 1969, Structural and petrologic summary of the Bethel granite, Bethel, Vermont: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 90 p.

Mould, W. P., 1944, Quarrying methods of the Barre, Vermont district (abs.): Economic Geology, v. 39, no. 1, p. 99-100.

Murthy, V. R., 1957, Bedrock geology of the East Barre area, Vermont: Vt. Geol. Surv., Bull., no. 10, p. 69-97, p. 113-114, SGL, VSL.

Naylor, R. S., 1979, Characterization of the Phanerozoic plutonic rocks of Vermont (abs.): Geol. Soc. Am., Northeastern Section, 14th Annual Mtg., Abs. with Prog., v. 11, no. 1, p. 46-47.

Nichols, T. C., Jr., 1972, Deformations associated with relaxation of residual stresses in the Barre granite (Devonian) of Vermont: Unpublished Master's thesis, Texas A & M University, College Station, TX.

Nichols, T. C., Jr., 1975, Deformations associated with relaxation of residual stresses in a sample of Barre granite from Vermont: U. S. Geological Survey, Professional Paper, no. 875, 32 p., SGL.

Nichols, T. C., Jr., and Friedman, M., 1973, Residual strains in Barre granite, Sioux quartzite, and Berea sandstone (abs.): American Geophysical Union, Transactions, v. 54, no. 4, p. 458.

Nichols, T. C., Jr., and Savage, W. Z., 1976, Rock strain recovery--Factor in foundation design: American Society for Civil Engineers, Specialty conference on rock engineering for foundations and slopes, 28 p., SGL.

Nichols, T. C., Jr., Savage, W. Z., and Brethauer, G. E., 1977, Deformations and stress changes that result from quarrying the Barre granite of Vermont: Energy and mineral resources recovery, American Nuclear Society Topical Meeting, U. S. Department of Energy, p. 791-803, SGL.

Nichols, T. C., Jr., and Varnes, D. J., no date, Rocks--Residual stress: U. S. Geological Survey, unpublished report, 18 p., SGL.

Nielson, D. L., Clark, R. G., Lyons, J. B., Englund, E. J., and Borns, D. J., 1976, Gravity models and mode of emplacement of the New Hampshire plutonic series: Geol. Soc. Am., Memoir, no. 146, p. 301-318.

con't

Perkins, G. H., 1898, Report of the marble, slate, and granite industries of Vermont: Rutland, VT, The Tuttle Company, 68 p., VSL.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1914, The mineral resources of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 430-439, SGL, VSL.

Perkins, G. H., 1916, Mineral resources of Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 293-298, SGL, VSL.

Perkins, G. H., 1918, Mineral resources of Vermont: Vermont State Geologist, 11th Report (1917-1918), p. 204-208, SGL, VSL.

Perkins, G. H., 1920, The geology of Mill Stone Hill, Barre, Vermont: Vermont Society of Engineers, Proceedings, p. 6-10.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Perkins, G. H., 1924, Mineral resources of Vermont: Vermont State Geologist, 14th Report (1923-1924), p. 344-351, SGL, VSL.

Perkins, G. H., 1927, Mineral resources of Vermont: Vermont State Geologist, 15th Report (1925-1926), p. 264-271, SGL, VSL.

Perkins, G. H., 1929, Mineral resources of Vermont: Vermont State Geologist, 16th Report (1927-1928), p. 382-386, SGL, VSL.

Perkins, G. H., 1930, Mineral resources of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 253-259, SGL, VSL.

Pough, F. H., no date, The history of granite: Barre, VT, The Barre Guild, 18 p., VSL.

Savage, W. Z., 1979, A model of the strain response to Barre granite to wetting and drying: U. S. Geol. Surv., Open-File Report, no. 79-768, 17 p.

Tomasi, Mari, 1958, Faces in granite: Vermont Life, v. 12, no. 2, p. 6-13, VHL, VSL.

Van Diver, B. B., 1970, Origin of biotite orbicules in "Bullseye Granite" of Craftsbury, Vermont: American Journal of Science, v. 268, no. 4, p. 322-340.

con't

Vermont Life, 1957, World's largest memorial granite plant: v. 11, no. 2, p. 27, VHL, VSL.

Von Chrustschoff, K. D., 1894, Über halokrystalline makrovariol ith ische Gesteine: Variolithischer granit von Craftsbury, Vermont, Nord-America: Academy of Imperial Science, Memoirs, v. 42, no. 3, p. 132-146.

Walbridge, J. H., 1897, The granite industry of Barre, Vermont: The granite city, illustrated edition of The Barre Enterprise, Barre, VT, VSL.

White, Walter, 1944, Granite, Barre, Washington County, Vermont: Unpublished information--This information is restricted for U. S. Geological Survey use. Non-Survey use most receive the Director's permission, 1 notebook.

White, W. S., 1946, Rock bursts in the granite quarries at Barre, Vermont: U. S. Geological Survey, Circular, no. 13, 22 p.

Supplement

Barton, W. R. and Ratte', C. A., 1976, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 7 p., SGL.

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Laurent, Roger, 1973, Composition and significance of the oversaturated syenitic complex of Barber Hill (Vermont), Essex (New York), and Champlain Valley (U.S.A.)(abs.): Geol. Soc. Am., Abs. with Prog., Northeastern Section, 8th Annual Mtg., v. 5, no. 2, p. 187-188.

Laurent, Roger and Pierson, T. C., 1973, Petrology of alkaline rocks from Cuttingsville and the Shelburne Penninsula, Vermont: Can. J. Earth Sci., v. 10, no. 8, p. 1244-1256, SGL.

Nichols, T. C., Jr., 1980, The state of stress in the Barre granite of Vermont and other near-surface crystalline rocks of North America; Paleo and present-day stress fields and the significance to engineering practice: Unpublished Ph.D. thesis, University of Colorado, Boulder, CO, 208 p.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vt. Div. Geol. and Earth Res., Open-File Rept., no. 1982-1, SGL.

White, D. H., Jr. and Ratte', C. A., 1979, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, 1978-1979, v. 2, 7 p., SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

THE KAOLINITIC CLAY PROVINCE

The kaolin province forms a narrow belt along the base of the Green Mountain Front in western Vermont. The history of production goes back to 1793 when local clay was used for the manufacture of pottery and fire-brick by Norton Pottery near Bennington. Deposits have been reported in Pownal, Bennington, Shaftsbury, Dorset, South Wallingford, Tinmouth, North Clarendon, Rutland, Brandon and Monkton. These deposits form discontinuous links in the kaolin belt.

Iron (as limonite) and manganese (as psilomelane, pyrolusite, and manganite) ores associated with the kaolin deposits were mined until the early 1900's, iron ore at Brandon (Forestdale) and Bennington, and manganese ore at South Wallingford. Early scientific workers (Dale 1903-04, Woodworth, 1903-04, Burt 1927-28) in the province attribute the origin of the kaolin to the residual weathering of feldspathic rocks caught up in the fault zone along the western base of the Green Mountains. More recently Ogden (1960 and 1969) has proposed a hydrothermal origin for the Monkton Kaolin deposit.

Kaolin deposits in the Shaftsbury-Bennington area were actively mined and processed and provided raw material for the paper, pottery, fireclay and brick industries. Greatest production came in 1930 when 11,000 tons of clay was mined by the Vermont Kaolin Corporation. The clay mining business in southwestern Vermont was a victim of the business depression of the 1930's. In recent years (1977) the Darlington Brick & Clay Products Company of Darlington, Pa. and (1979) the Holland Chemical Company of Adams, Ma. have shown an interest in these deposits.

The Brandon (Forestdale) kaolin deposit was worked from 1902 to 1925 and produced 80,000 tons of kaolin. This deposit is reported to be practically worked out (Jacobs, 1933-34).

The Monkton kaolin industry got underway in the early 1800's having been perhaps the first kaolin deposit to be discovered in the U. S. in 1792. The American Kaolin Company produced an average of 2000 tons per year from 1883 - 1890. Various firms produced kaolin intermittently until 1930. From 1930 until 1944 the firm of Frank E. Bushey & Sons produced about a thousand tons per year to supply the needs of the Rutland Fire Clay Company. In 1956 the Vermont Kaolin Corporation purchased mineral rights from Mr. Leon V. Bushey. After several years of exploratory work, laboratory testing and plant construction, only 9,235 tons of clay were produced and in 1966 the operation closed down. Apparently the beneficiation process was not sophisticated enough to remove discoloring impurities, particularly graphite material. In addition, the natural product being quite coarse textured required expensive grinding, separating and drying techniques. The cost to market a product meeting the specifications of the modern paper making industries became prohibitive.

K A O L I N --- C L A Y

Burt, F. A., 1929, Origin of the Bennington Kaolins: Vermont State Geologist, 16th Report (1927-1928), p. 65-84, SGL.

Dale, T. N., 1904, Note on the geological relations of the Brandon lignite deposit: Vermont State Geologist, 4th Report (1903-1904), p. 163-165, SGL.

Dewey, Chester, 1827, Porcelain clay: American Journal of Science, v. 12, p. 298-299.

Gavish, Eliezer and Reynolds, R. C., 1970, Structural changes and isomorphic substitution in illites from limestones of variable degrees of metamorphism: Isreal Journal of Chemistry, v. 8, no. 3, p. 477-485.

Hill, R. N., Jr., 1961, Pure-white and plenty (kaolin): Vermont Life, v. 16, no. 1, p. 38-43, VHL, VSL.

*Jacobs, E. C., 1927, The clay deposits and clay industries of Vermont: Vermont State Geologist, 15th Report (1925-1926), p. 191-221, SGL, VSL.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Millett, J. A., 1967, The clay mineralogy of the bottom sediments of the Champlain Basin from Thompson's Point, Vermont to the Ausable River, New York: Unpublished Master's thesis, University of Vermont, Burlington, Vermont, 44 p.

Nevius, J. N., 1897, Kaolin in Vermont: Engineering and Mining Journal, v. 64, p. 189.

Ogden, D. G., 1960, Geology and origin of the kaolin at East Monkton, Vermont: Unpublished Master's thesis, University of Vermont, Burlington, Vermont, 130 p.

Ogden, D. G., 1969, Geology and origin of the kaolin at East Monkton, Vermont: Vermont Geological Survey and Vermont Department of Water Resources, Studies in Economic Geology, no. 3, 40 p., VSL.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

con't

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1914, The mineral resources of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 430-439, SGL, VSL.

Perkins, G. H., 1916, Mineral resources of Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 293-298, SGL, VSL.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Peterson, E. C., 1967, Vermont--Sources of aluminum: Potential sources of aluminum, U. S. Bureau of Mines, Information Circular, IC-8335, p. 132-133, SGL.

Sheldon, J. M. A., 1900, Concretions from the Champlain clays of the Connecticut Valley: Boston, Massachusetts, The University Press, John Wilson and Sons, Inc., 45 p., VHL.

Solomon, S. M., 1975, The engineering properties and geologic history of the clays comprising the Weybridge slump: Unpublished Senior thesis, Middlebury College, Middlebury, Vermont, 38 p.

Wark, J. A., 1968, Report on a resistivity survey of the Monkton kaolin deposit and drill hole exploration: Vermont Geological Survey and Vermont Department of Water Resources, Studies in Economic Geology, no. 2, 31 p., VSL.

White, C. J., 1963, Study of the Champlain Valley clays in the vicinity of Middlebury, Vermont: Unpublished Senior thesis, Middlebury, Vermont, 21 p.

Woodworth, J. B., 1904, The Brandon clays: Vermont State Geologist, 4th Report (1903-1904), p. 166-173, SGL, VSL.

Supplement

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Black, Martin, 1976, The St. George fault, Monkton Ridge, Vermont (abs.): Green Mountain Geologist, v. 3, no. 1, SGL.

Doll, C. G., 1956, Report of the State Geologist and Vermont Geological Survey: For the biennium, July 1, 1954-June 30, 1956, 8 p., SGL.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vermont Division of Geology and Earth Resources, Open-File Report, no. 1982-1, scale 1:250,000, SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montprlier, VT.

THE OIL AND GAS PROVINCE

The first attempt to find oil and gas in Vermont was made in the Lake Champlain Basin in the spring of 1957. A wildcat well was drilled to a depth of approximately 4,500 feet on the Isadore Yandow farm four miles northwest of St. Albans. Since that time four additional wells have been drilled in the Champlain sedimentary basin, the Gregoire I and II drilled at Mallet's Bay in Colchester in 1959-60, the Petrofina well drilled on the Harry Hutchins farm in So. Alburg in 1964, and the E. S. Baker #I well drilled in 1968 on the Everett S. Baker farm on Grand Isle. Some gas shows were reported, but all wells were abandoned. The deepest well (Gregoire I) is reported to have penetrated to a depth of 5,075 feet. Although commercial quantities of natural gas have been discovered in the Canadian extension of the Champlain sedimentary basin little interest has been generated in Vermont since the abandonment of E. S. Baker #I at 3,500 feet.

The Cambrian Potsdam formation is believed to be the potentially productive horizon, as well as bioherm and biostrome zones in carbonate rocks. In the Champlain basin Ordovician dolomites and shales thickened by faulting and folding cover the Potsdam. A potential for oil and gas traps in sedimentary horizons beneath the Green Mountain overthrust sheet (northern extension of the Eastern Overthrust Belt) extends the province eastward beyond the Green Mountain Front.

There are occurrences of natural gas in water wells in northwestern Vermont. A report was made by the Federal Energy Research and Development Administration in 1975 on the presence of soil gas in the Milton area. The amount and nature of this gas being comparable to that found above productive gas fields elsewhere. This evidence plus positive finds of commercial quantities of natural gas in Canada encourage continued speculation on the oil and gas potential of the western Vermont sedimentary basin. A proposal submitted to the Federal Energy Research and Development Administration in 1976 by the Vermont State Geologist and the Vermont Energy Office to drill a deep stratigraphic test hole and hydrocarbon probe was not funded.

The area west of a line drawn somewhat west of the central spine of the Green Mountains from Richford (north) to Stamford (south) can be considered as Vermont's Oil and Gas Province. The results of future exploration may alter the dimensions of this province.

In 1981 the Ohio Oil and Gas Company, a leasing brokerage from Fowler, Ohio obtained oil and gas leases on over 250,000 acres in western Vermont. In January of 1982 Columbia Gas Transmission Company and Louisiana Land and Exploration Company announced the purchase of these leases from the Ohio Company, and their intent to start seismic exploration in the summer of 1982.

OIL AND GAS

Armstrong, F. E., 1975, Status summary, Champlain Valley investigation (soil-gas analysis): Unpublished report from Bartlesville Energy Research Center, Bartlesville, OK, U.S.E.R.D.A., 8 p., SGL.

Bigelow, Tom, 1982, Vermont gas potential lures speculators: Northeast Oil Reporter, v. 2, no. 8, p. 48-51.

Doll, C. G., Report of the State Geologist for the following years:
1954-1956 SGL
1956-1958 SGL
1960-1962 SGL
1962-1964 SGL
1964-1966 SGL
1966-1968 SGL
1968-1970 SGL
1970-1972 SGL
1972-1974 SGL

Doll, C. G., 1976, Deep drill hole probe for hydrocarbons in northwestern Vermont--A proposal to energy research and development: Unpublished report, 17 p., SGL.

Gardner, F. J., 1956, Want to be the first in Vermont?: Oil and Gas Journal, March 26, v. 54, p. 191.

Gardner, F. J., 1964, Exploration surges into New England: Oil and Gas Journal, October 12, v. 62, p. 239.

Khouri, L., 1977, On Vermont's great oil boom: Vermont Life, Spring 1977, p. 59-61, SGL, VHL, VSL.

Page, L. R., 1971, Petroleum potential of New England and selected references for region 10: American Association for Petroleum Geologists, Memoir, no. 15, p. 1274-1289.

Report of the New York-Vermont Interstate Commission on the Lake Champlain Basin, 1965, Mineral Resources Committee Report, p. 79-82, VSL.

Taylor, E. F., 1963, Wildcat drilling is coming to Vermont: Oil and Gas Journal, November 18, p. 230-231.

Taylor, E. F., 1964, Vermont has oil, gas possibilities: World Oil, v. 158, no. 7, p. 142, 144, 146.

Vermont State Natural Gas and Oil Resources Commission, 1959, First Biennial report, p. 1-8, VSL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

THE SLATE PROVINCE

Current slate production comes from the Cambrian St. Catherine Formation and the Ordovician Poultney and Indian River Slate Formation as mapped by Shumaker (1967) which are dominant formations within the Taconic Allochthon in southwestern Vermont (see Mineral Resource Province Map). An outline of this formation essentially parallels the margins of the slate province. The Vermont portion of the Vermont-New York Slate mining district is located in a narrow belt bordered on the west by the state line and on the east by the thrust line delineating the western margin of the western Bird Mountain Slice of Shumaker (1967).

Some of the first slates to be quarried in Vermont came from the Devonian Littleton Formation in Dummerston, Brattleboro and Guilford in southeastern Vermont. These quarries were mentioned in the first state geologist's report on the Geology of Vermont (Adams, 1845). Slate has also been quarried from the Devonian Northfield Formation in Northfield. These slates are black or dark gray in color and perhaps are better classified as phyllites. There has been no commercial production from these quarries since the early 1900's.

The current production of slate in Vermont comes from the Vermont-New York Slate Mining District in southwestern Vermont-east central New York. Approximately ten quarries are currently being operated in Vermont. The quarrying and milling operations employ approximately 300 people and the size of the operations vary from a two or three man family working part-time, to the larger quarrying-milling operation of Vermont Structural Slate Co. The Vermont-New York slates are unique in durability and color. The colors are red, unfading green, fading green (will turn brown in time), purple and mottled (green and purple). The slate is used for floor and counter tile, roofing slate, flagging, monumental, building veneer and other structural items.

The U. S. Bureau of Mines is currently conducting research on the use of waste slate as a resource. Several products have been produced at the research level. These include glass ceramics and fibers, light weight concrete aggregate and skid resistant highway aggregate. Whether or not these products can be produced and marketed economically is not yet known.

Vermont slate supplies local, national and international markets.

Current practice of the slate industry is to continue to deepen existing quarries or to extend them along strike. Also several old quarries have been reactivated. An abundance of resource has not yet required off-property exploration.

Arthur D. Little, Inc. completed a comprehensive study of the Vermont-New York Slate industry in October, 1980. This study conducted under a U. S. Bureau of Mines contract presents several recommendations for improving quarrying, milling and marketing techniques in the slate industry.

Baker, E. R. and Davidson, A. R., 1912, The strength and weathering qualities of Vermont roofing slates: Vermont State Geologist, 8th Report (1911-1912), p. 220-231, SGL, VSL.

Balk, Robert, 1953, Faltenachsen in Überschiebungszonen: Geologische Rundschau, Band 41, Stuttgart, Vermany P. 90-103 (with English summary).

Bristol, W. A., 1912, High tension testing of Vermont slate and marble: Vermont State Geologist, 8th Report (1911-1912), p. 196-219, SGL, VSL.

Dale, T. N., 1899, The slate belt of eastern New York and western Vermont: U. S. Geological Survey, 19th Annual Report, part 3, p. 153-300, VSL.

Dale, T. N., 1906, Slate deposits and slate industry of the United States: U. S. Geological Survey, Bulletin, no. 275, 154 p.

Dale, T. N., 1914, Slate in the United States: U. S. Geological Survey, Bulletin, no. 586, 220 p.

Earney, F. C., 1963, The slate industry of western Vermont: Journal of Geog., v. 62, no. 7, p. 300-309, VSL.

Hathaway, C. W., 1947, A history of the slate industry of the Vermont-New York district: Unpublished Master's thesis, University of Vermont, Burlington, VT, 93 p.

Hitchcock, C. H., 1858, On fractured ledges of slate in Vermont: American Association for the Advancement of Science, Proceedings, v. 11, part 2, p. 51-55.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Kenyon, S. L., 1977, Hortonville slate west of Middlebury, Vermont: Unpublished Senior thesis, Middlebury College, Middlebury, VT, 63 p.

Larrabee, D. M., 1939, The colored slates of Vermont and New York: Engineering and Mining Journal, v. 140, no. 12, p. 47-53, also v. 141, no. 1, p. 48-52.

Morrow, J. A., 1970, A century of hard rock, the story of Rising and Nelson Slate Co., West Pawlet, Vermont: Granville, NY, Grastorf Press, 32 p.

Perkins, G. H., 1898, Report of the marble, slate, and granite industries of Vermont: Rutland, VT, The Tuttle Co., 68 p., VSL.

con't

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1914, The mineral resources of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 430-439, SGL, VSL.

Perkins, G. H., 1916, Mineral resources of Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 293-298, SGL, VSL.

Perkins, G. H., 1918, Mineral resources of Vermont: Vermont State Geologist, 11th Report (1917-1918), p. 204-208, SGL, VSL.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Perkins, G. H., 1924, Mineral resources of Vermont: Vermont State Geologist, 14th Report (1923-1924), p. 344-351, SGL, VSL.

Perkins, G. H., 1927, Mineral resources of Vermont: Vermont State Geologist, 15th Report (1925-1926), p. 264-271, SGL, VSL.

Perkins, G. H., 1929, Mineral resources of Vermont: Vermont State Geologist, 16th Report (1927-1928), p. 382-386, SGL, VSL.

Perkins, G. H., 1930, Mineral resources of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 253-259, SGL, VSL.

Rappaport, Neil, photographer, 1972, Slatemaker---James Covino (transcribed by Vincent E. Covino): Vermont Life, v. 27, no. 2, p. 14-21, VHL, VSL.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vermont Division of Geology and Earth Resources, Open-File Report, no. 1980-1, scale 1:250,000, SGL.

Richardson, C. S., 1854, The slate quarries of Vermont: Mining Magazine, v. 2, p. 271-282.

Rogers, F. F., 1956, Vermont slate: Vermont Life, v. 10, no. 2, p. 2-7, VHL, VSL.

con't

Watson, W. I., Shorey, C. E., Whittier, A. J., Ohlsson, E., and Miller, A. J., 1980, Study of the slate mining industry of Vermont/New York: Prepared by Arthur D. Little, Inc., Acorn Park, Cambridge, MA, Report no. C-83918, Prepared for the U. S. Dept. of the Interior, Bureau of Mines, contract no. J0199075, 136 p., SGL.

Wright, W. H., III, 1969, Phases of folding in the slate belt of west-central Vermont (abs.): Geological Society of America, Abstracts, Northeastern Section, part 1, p. 64.

Wright, W. H., III, 1970, Rock deformation in the slate belt of west-central Vermont: Unpublished Ph.D. thesis, University of Illinois, Urbana, IL.

Wright, W. H., III, 1971, Rock deformation in the slate belt of west-central Vermont: Dissertation Abstracts International, v. 31, no. 9, p. 5430B-5431B.

Zen, E-an, 1960, Petrology of Lower Paleozoic rocks from the slate belt of western Vermont: Petrographic provinces, igneous, and metamorphic rocks, International Geological Congress, 21 Session, 1960, Norden, part 13, p. 362-371, SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

THE SULFIDE PROVINCE

Vermont's Orange County Copper Mining District and the Essex Copper mine lie within the Connecticut Valley-Gaspe' Synclinorium and Bronson Hill Anticlinorium Tectonic Provinces and the large Appalachian province of stratabound (massive) sulfide deposits (Gair and Slack, 1979). Other small mines, prospects and noted metallic sulfide mineral occurrences lie within this major tectonic-mineral province. Isolated occurrences are known within the Green Mountain Anticlinorium tectonic province.

Lead-zinc sulfide mineralization is known to exist in the Cambrian Winooski-Dunham lithologies which extend from Franklin (north) to Bennington (south) Counties. The only known mines (now abandoned) were the Oram prospects at Brandon. This narrow, linear province with sporadic occurrences of galena-sphalerite may be thought of as the Foreland lead-zinc province. Lead-zinc occurrences in this province may be similar to those in the southern Appalachian zinc province where the sulfide mineralization is associated with both tectonic and collapse breccias or localized along faults and fault intersections in Cambrian (Knox-type) dolomitized limestones. This Foreland lead-zinc province warrants detailed exploration.

No metallic minerals are currently being mined in Vermont. The sulfide ores in the Orange County district were discovered in 1793 and mines began to operate for the production of copper in the early 1830's. Vermont was the chief copper producer in the United States until the Michigan copper ores were exploited in 1846. The Vermont mines operated sporadically through the 1950's. The closing of the Elizabeth mine at South Strafford in 1958 brought an end to metal mining in Vermont. Ore minerals have not been exhausted in the Orange County copper district. However, the ore grade is marginal and the complexity of the structure makes mining extremely difficult. No strong interest has been shown in the district for more than twenty years.

The district was left to remain as a significant scar on the surrounding landscape. Nature has been incapable of healing the acid-sulfur wastes. Strong environmental opposition is likely to deter future mining in the district unless it can be demonstrated that the present day mining technology is capable of rehabilitating the landscape including existing as well as newly generated wastes and mining scars.

Known sulfide mineralization including old prospects and mines are indicated on the Mineral Resource Province Map by the letter S. No attempt has been made to outline a province.

COPPER, LEAD, ZINC AND OTHER SULFIDES

Abbott, Collamer, 1964, Vermont's pioneer copper plant: The New England Galaxy, Fall 1964, v. 6, no. 2, p. 33-41.

Abbott, Collamer, 1971, Copper mining in the eastern United States during the nineteenth century: International Review of the History of Banking, v. 4, p. 425-448.

Abbott, Collamer, 1973, Green Mountain copper, the story of Vermont's red metal: Randolph, VT, Herald Printery, 36 p., SGL.

Anderson, C. S., 1931, Mining and milling in the Vermont copper district: Engineering and Mining Journal, v. 131, p. 208-210.

Benson, C. B., Wangaard, J. C., and Johnson, H. A., 1950, Elizabeth Mine reorganized for efficient production: Mining Congress Journal, v. 36, p. 18, 23.

Buerger, N. W., 1935, The copper ores of Orange County, Vermont: Economic Geology, v. 30, no. 4, p. 434-443, VHL, SGL.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont: Geological Society of America, Bulletin, v. 56, no. 5, p. 515-588.

Canney, F. C., 1965, Geochemical prospecting investigations in the copper belt of Vermont: U. S. Geological Survey, Bulletin, no. 1198-B, p. b1-b28, SGL.

Cazin, F. M. F., no date, Genesis of ore deposits, pamphlet, p. 18-22, VHL.

Child, Hamilton, 1888, Geology and copper mines of Orange County, Vermont: Gazeteer and business directory of Orange County, Vermont, 1762-1888: The Journal Office, Syracuse, NY, p. 11-33, VSL.

Collins, B. I., 1971, The copper geochemistry of a small mine tailings stream in east-central Vermont: Unpublished Master's thesis, Dartmouth College, Hanover, NH, 36 p.

Collins, B. I., 1973, The concentration control of soluble copper in a mine tailings stream: Geochimica et Cosmochimica Acta, v. 37, no. 1, p. 69-75, SGL.

Doll, C. G., 1969, Report on the Cuttingsville pyrrhotite deposit, Cuttingsville, Vermont: Vermont Geological Survey and Vermont Department of Water Resources, Studies in Economic Geology, no. 4, 8 p., SGL, VSL.

DuClos, K. F. and Thresher, M. C., ed., 1976, The history of Braintree, Vermont, v. II, 1883-1975: Montpelier, VT, Capital City Press, p. 47-50, SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Eric, J. H., 1943, Preliminary geologic report on the Berkshire Mine, Berkshire, Franklin County, Vermont: U. S. Geological Survey, Open-File Report. no. 79-355, 6 p., SGL.

Eric, J. H. and J. G. Dennis, 1958, Geology of the Concord-Waterford area, Vermont: Vt. Geol. Surv., Bull., no. 11, p. 62, SGL. VSL.

Espenshade, G. H., 1940, Eastern sulfides, including Vermont: Unpublished information--This information is restricted for U. S. Geological Survey use. Non-Survey use must receive the Director's permission, 1 notebook.

Fay, A. H., 1909, The Vermont Copper Company: Engineering and Mining Journal, v. 88, p. 364-365.

Gair, J. E. and J. F. Slack, 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits of the U. S. Appalachians: U. S. Geol. Surv., Open-File Report, no. OF-79-1517, 4 sheets.

Grant, R. W., 1970, Geochemical investigations in Essex and Caledonia Counties, Vermont: Vt. Geol. Surv., Economic Geology Report, no. 7, 8 p., SGL, VSL.

Hermance, G. L., Neumann, G. L., and Mosier, McHenry, 1949, Investigation of Ely Mine copper deposit, Orange County, Vermont: U. S. Bureau of Mines, Report of Investigations, no. 4395, 11 p., VSL.

Howard, P. F., 1957, Structure and rock alteration at the Elizabeth Mine, Vermont: Unpublished Ph.D. thesis, Harvard University, Cambridge, MA, 197 p.

Howard, P. F., 1959, Structure and rock alteration at the Elizabeth Mine, Vermont: Economic Geology, v. 54, no. 7, p. 1214-1249.

Howard, P. F., 1959, Structure and rock alteration at the Elizabeth Mine, Vermont: Economic Geology, v. 54, no. 8, p. 1414-1443.

Howard, P. F., 1969, Geology of the Elizabeth Mine, Vermont: Vermont Geological Survey, and Vermont Department of Water Resources, Studies in Economic Geology, no. 5, 73 p., SGL, VSL.

Howe, H. M., 1886, The Elizabeth Copper Mine, Vermont: Engineering and Mining Journal, v. 42, p. 327.

Jackson, C. T., 1854, On a new mine of gold, silver, lead, and copper recently opened at Bridgewater, Vermont: Boston Society of Natural History, Proceedings, v. 5, p. 62.

Jacobs, E. C., 1916, Copper mining in Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 192-199, SGL, VSL.

Jacobs, E. C., 1918, Progress in copper mining and milling: Vermont State Geologist, 11th Report (1917-1918), p. 141-147, SGL, VSL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Jacobs, E. C., 1942, Reopening of the Vermont copper mines: Vermont State Geologist, 23rd Report (1941-1942), p. 1-16, SGL, VSL.

Jacobs, E. C., 1944, The Vermont Copper Company, Inc.: Vermont State Geologist, 24th Report (1943-1944), p. 1-13, SGL, VSL.

Jenks, W. F., 1971, Tectonic transport of massive sulfide deposits in submarine volcanic and sedimentary host rocks: Economic Geology, v. 66, p. 1215-1224, SGL.

Jones, R. W., 1918, The manganese deposits of South Wallingford, Vermont: Engineering and Mining Journal, v. 105, p. 779.

Judson, J. N., 1909, The Vermont Copper Company: Engineering and Mining Journal, v. 88, p. 524-525.

Kinkle, A. R., Jr. and Peterson, N. P., 1962, Copper in the United States: U. S. Geological Survey, Mineral Investigations Resource Map, MR-13.

Linsley, D. C., 1875, Report of a survey of the copper mine of the Vermont Copper Mining Company: Burlington, VT, Mark Thompson, 14 p., VSL.

Lutjen, G. P. and Kearney, J. G., 1953, New life for Vermont's 160 year old copper mine: Engineering and Mining Journal, v. 154, p. 72-75

Mann, J. A., 1943, Vermont copper and an associated deposit: Unpublished Senior thesis, Princeton University, Princeton, NJ.

McKinstry, H. E., 1954, Economic geology of the Elizabeth Mine, South Strafford, Vermont: Guidebook, New England Intercollegiate Field Conference, 46th Annual Meeting, p. 25.

McKinstry, H. E. and Mikkola, A. K., 1954, The Elizabeth Copper Mine, Vermont: Economic Geology, v. 49, no. 1, p. 1-30.

Meacham, Daniel, 1864, Papers relating to copper mining on his farm, Newport, Vermont, May-June 1864: Vermont Historical Society Library, Montpelier, VT, 5 p.

Mikkola, A. K., 1952, Mineralization and rock alteration in the Elizabeth copper deposit, Vermont (abs.): Economic Geology, v. 47, no. 7, p. 774, also Geological Society of America, Bulletin, v. 63, no. 12, part 2, p. 1279.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL,

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1930, Minerals of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 151-178, SGL, VSL.

Peters, E. D., 1891, The Ely mines of Vermont: Engineering and Mining Journal, v. 52, p. 6-7.

Rolph, A. L. and Annis, M. P., 1980, A basinal sequence in the Gile Mountain Formation at the eastern edge of the Strafford Dome in the vicinity of the Elizabeth Mine, Vermont, copper belt (abs.): Geol. Soc. Am., 93rd Annual Mtg., Abs. with Prog., p. 511.

Schmidt, R. G., 1978, The potential for porphyry copper-molybdenum deposits in the eastern United States: U. S. Geological Survey, Professional Paper, no. 907-E.

Skinner, B. J. and Milton, D. J., 1955, The Elizabeth Copper Mine, Vermont: Economic Geology, v. 50, no. 7, p. 751-752.

Slack, J. F., 1981, Stratabound sulfide deposits of the New England region: An overview (abs.): Geol. Soc. Am., Abs. with Prog., Northeastern Section, 16th Annual Mtg., p. 177.

Smith, P. S., 1904, The copper sulphide deposits of Orange County, Vermont: Unpublished Ph.D. thesis, Harvard University, Cambridge, MA.

Smyth, H. L. and Smith, P. S., 1904, The copper deposits of Orange County, Vermont: Engineering and Mining Journal, v. 77, p. 677-678.

Stoiber, R. E., 1962, Cobalt in pyrrhotite and chalcopyrite of the Elizabeth Mine, South Strafford, Vermont (abs.): Economic Geology, no. 6, p. 1012-1013.

Stoiber, R. E., 1963, Minor cobalt in pyrrhotite and chalcopyrite of the Elizabeth Mine, South Strafford, Vermont (abs.): Geological Society of America, Special Paper, no. 73, p. 251.

Vermont Copper Co., Inc., 1947-1949, The Elizabeth Miner: House organ of the Vermont Copper Co., Inc., VSL.

Weed, W. H., 1904, Notes on the copper mines of Vermont: U. S. Geological Survey, Bulletin, no. 225, p. 190-199.

Weed, W. H., 1911, Copper deposits of the Appalachian states: U. S. Geological Survey, Bulletin, no. 455, p. 18-33.

Wheeler, H. A., 1883, Copper deposits of Vermont: Columbia College, School of Mines, Quarterly, v. 4, p. 219-224.

White, Walter, 1943, Thetford lead-zinc prospect, Mt. Cube quadrangle, Vermont: Unpublished information--This information is restricted for U. S. Geological Survey use. Non-Survey use must receive the Director's permission. notes and administrative report.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

White, Walter, 1943, Udall Mine, Lamoille County, Vermont: Unpublished information--This information is restricted for U. S. Geological Survey use. Non-Survey use must receive the Director's permission, notes and maps.

White, Walter, 1943, Vermont copper district, Orange County, Vermont: Unpublished information--This information is restricted for U. S. Geological Survey use. Non-Survey use must receive the Director's permission, 11 notebooks, miscellaneous material and aerial photos.

White, W. S., 1944, Geology of the Elizabeth Copper Mine, Vermont: U. S. Geological Survey, Open-File Report.

White, W. S., 1952, Structural control in the Vermont copper belt (abs.): Economic Geology, v. 47, no. 7, p. 779, also Geological Soceity of America, Bulletin, v. 63, p. 1312-1313.

White, W. S. and Eric, J. H., 1944, Geology of the Orange County copper district: U. S. Geological Survey, Strategic Minerals Preliminary Map, scale 1:31,680.

*White, W. S. and Eric, J. H., 1944, Preliminary report on the geology of the Orange County copper district, Vermont: U. S. Geological Survey, Open-File Report.

White, W. S., Eric, J. H., and Amsden, T. W., 1943, Preliminary report on Orange and Gove copper mines, Strafford, Vermont: U. S. Geological Survey, Open-File Report, no. 79-352, 6 p.

White, W. S., Eric, J. H., and Amsden, T. W., 1946, Preliminary geologic report on the Udall Mine, Wolcott, Lamoille County, Vermont: U. S. Geological Survey, Open-File Report. [REPORT NOT AVAILABLE... WITHDRAWN!]

Wilson, C. M., 1958, Royal red: Ore from America's oldest copper mine has served the world's changing needs since 1793: Vermont Life, v. 12, no. 3, p. 14-21, VHL, VSL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

COPPER SUPPLEMENT:

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Bottner, R. W., 1977, Wallrock alteration associated with pyrrhotite mineralization at Curringsville, Vermont: Unpublished Master's thesis, University of Vermont, Burlington, VT.

Gair, J. E. and Slack, J. F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits of the U. S. Appalachians: U. S. Geological Survey, Open-File Report, no. OF-79-1517, 3 maps, SGL.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vt. Division of Geology and Earth Resources, Open-File Report, no. 1982-1, scale 1:250,000, SGL.

Slack, J. (investigator), 1980, Tourmaline associated with New England massive sulfide deposits (abs.): U. S. Geological Survey, Professional Paper, no. 1175, p. 7.

Slack, J. F., 1981, Stratabound sulfide deposits of the New England region: An overview (abs.): Geological Society of America, Abstracts with Program, Northeastern Section, 16th Annual Meeting, v. 13, no. 3, p. 177, SGL.

Slack, J. F. and Annis, M. P., 1981, Time-space relations of tourmaline-rich rocks at the Elizabeth Mine and vicinity, Vermont Copper belt (abs.): Geological Society of America, Abstracts with Program, Northeastern Section, 16th Annual Meeting, v. 13, no. 3, p. 177, SGL.

Pearre, N. C. and Calkins, J. A., 1957, Mineral deposits and occurrences in Vermont exclusive of clay, sand and gravel, and peat: U. S. Geol. Surv., Mineral Investigations Resources Map, MR-5, SGL.

Schmidt, R. G., 1978, The potential for porphyry copper-molybdenum deposits in the eastern United States: U. S. Geol. Surv., Prof. Paper, no. 907-E, 31 p., SGL.

SGL--Available at the Office of the State Geologist, Montpelier, Vermont.

THE ULTRAMAFIC PROVINCE

Asbestos: The asbestos mining district is located in the upper Missisquoi River Valley in Orleans and Lamoille counties. Current mines and milling operations are located on the eastern flank of Belvidere Mountain in the towns of Lowell and Eden. The mines and mill are being operated by the Vermont Asbestos Group, a primarily worker-owned industry whose main office is at Hyde Park, Vermont. Although production is small compared with that of producers in Quebec, Vermont ranks second in the production of chrysotile asbestos in the United States. Vermont's asbestos industry supplies both national and foreign markets.

Asbestos minerals are associated with serpentinized ultramafic bodies. The larger bodies are composed of central cores of massive dunite and peridotite which grade outward to massive or sheared serpentinite. Chrysotile asbestos occurs sparcely as cross-fiber veins in the more massive portions of the ultramafic bodies and as slip-fiber veins in the highly sheared serpentinites.

Modern theories on the tectonic emplacement of the ultramafic bodies may modify exploration procedures and encourage more extensive off-property searches. Current industry practice involves the expansion of existing open pit mines which has been successful in meeting market demands.

The Vermont Centennial Geologic map (Doll, 1961) shows the "ultramafic belt" extending the full length of the state with ultramafic bodies located in the Hazens Notch, Stowe, Ottauquechee, and Missisquoi Formations of Cambrian and Ordovician age. This map, with some modification, (see Mineral Resource Province Map) serves as a mineral province-mineral potential map. The Upper Missisquoi Valley asbestos mining district occupies the northern extremity of the ultramafic province.

Current environmental concerns regarding the protection of the health of asbestos workers and users has placed stringent air quality standards on the mining and milling of asbestos in the United States. Former user markets for asbestos are seeking substitutes. Both factors have had a major impact on the Vermont asbestos industry.

Talc and Soapstone: Like the asbestos mineralization described above, talc (and its massive variation - soapstone) is associated with serpentinized ultramafic bodies. The ultramafic bodies containing talc (steatite) are composed of a central core of serpentinite surrounded by a shell of talc-carbonate rock followed by an outer shell of talc (steatite). The production of talc and serpentine asbestos are genetically related but the steatitization is the latest, more extended metasomatic event which did not affect all of the ultramafic bodies in the province. Metasomatism involved the movement of H_2O, CO_2, MgO and SiO_2.

The talc-soapstone mineralization coincides with that described above for asbestos and is included within the ultramafic province. Known occurrences in north central Vermont are at Johnson (currently being mined by Eastern Magnesia Talc Co.), the Rousseau prospect, and Sterling Pond prospect in Lamoille County, the Barnes Hill, Waterbury and Mad River localities in Washington County, and the East Granville locality in Orange County. These known occurrences are contained in the northern talc mining district (see Plate I).

The talc mines of Windsor Minerals Inc., in Hammondsville and Ludlow, the Vermont Talc Company mine in Andover, and the Vermont Soapstone Company mine in Chester are included in the southern talc mining district (see Mineral Resource Province Map).

Vermont leads the nation in talc production. Products manufactured from Vermont talc are popular in the national and international marketplace.

Verde Antique (Serpentinite): "Verde antique marble" is the commercial name applied to the highly polished dark green serpentinite which has shear fractures cemented by veins of white carbonate mineralization. Verde antique is currently mined by the Vermont Marble Company (OMYA) at Quarry Hill, Rochester, Vermont. An abandoned verde antique mine is located in Roxbury. Verde antique quality serpentinite is also found at the Waterbury, Barnes Hill and Mad River localities. These serpentinite bodies are included in the northern talc mining district.

Because of the natural mineralogical associations of serpentine asbestos and talc similar environmental health concerns pervail in the mining, milling and product use where these resources are concerned. Particular attention must be given to quality control where these products are sold for human consumption.

Chromite: Chromite mineralization is known to exist in several of the serpentine bodies. Noticeable quantities of chromite have been encountered at the Rochester verde antique quarry and Belvidere Mountain.
Magnetite: Magnetite has been mined in Troy, Vermont.
Ultramafic Rock as a future resource: Future resources may be realized from the use of ultramafic rock as a heat retention material in solar heat storage facilities. Research on serpentinite mine waste conducted in Canada (University of Sherbrooke) and in the United Stated (Bureau of Mines, Federal Highway Administration) has produced several potentially marketable products. Among these are light weight concrete aggregate, refractory bricks, and synthetic skid resistant road aggregate.

BIBLIOGRAPHY

FOR

MINERAL RESOURCES IN THE

ULTRAMAFIC PROVINCE

Bain, G. W., 1932, Chrysotile asbestos, chrysotile solutions: Economic Geology, v. 27, no. 3, p. 281-296.

Bain, G. W., 1934, Serpentinization, origin of certain asbestos, talc, and soapstone deposits: Economic Geology, v. 29, no. 4, p. 397-400.

Bain, G. W., 1942, Vermont talc and asbestos deposits: Newhouse, W. H., ed., Ore deposits as related to structural features, Princeton, NJ, Princeton University Press, p. 255-258.

Bain, G. W., 1969, Vermont talc and asbestos deposits: Newhouse, W. H., ed., Ore deposits as related to structural features, New York, NY, Hafner Pub., Inc., p. 255-258.

Bowles, Oliver, 1959, Asbestos--A materials survey: U. S. Bureau of Mines, Information Circular, no. 7880, 94 p.

Burmeister, H. L. and Matthews, I. E., 1962, Mining and milling methods and costs, Vermont Asbestos Mines, The Ruberoid Company, Hyde Park, Vermont: U. S. Bureau of Mines, Information Circular, no. 8068, 43 p.

Cady, W. M., Albee, A. L., and Chidester, A. H., 1963, Bedrock geology and asbestos deposits of the upper Missisquoi Valley and vicinity, Vermont: U. S. Geological Survey, Bulletin, no. 1122-B, 78 p., SGL.

Chidester, A. H., 1961, Economic geology of the Belvidere Mountain asbestos area, Vermont Asbestos Mines, division of the Ruberoid Company: Doll, C. G., ed., Guidebook, New England Intercollegiate Geological Conference, 53rd Annual Meeting, section 3, trip B-1, 1 p., VSL.

Chidester, A. H., 1968, Evolution of the ultramafic complexes of northwestern New England: Zen, E-an, White, W. S., Hadley, J. B., Thompson, J. B., Jrs., eds., Studies of Appalachian geology, northern and maritime, New York and London, Interscience Publishers, John Wiley and Sons, chapter 26.

Chidester, A. H., Albee, A. L., and Cady, W. M., 1978, Petrology, structure, and genesis of the asbestos-bearing ultramafic rocks of the Belvidere Mountain area in Vermont: U. S. Geological Survey, Professional Paper, no. 1016, 95 p., SGL.

Chidester, A. H. and Shride, A. F., 1962, Asbestos in the United States: U. S. Geological Survey, Mineral Investigations Resource Map, MR-17, SGL.

Clairborne, W. L., 1976, Vermont Asbestos Group: Worker-owned mine shows bright prospects: Vermont Life, v. 30, no. 3, p. 9-13, VHL, VSL.

Crane, C. E., 1954, Vermont makes silk from stone--The story of the nation's largest asbestos operation located on a remote mountainside of northern Vermont: Vermont Life, v. 8, no. 3, p. 2-9, VHL, VSL.

Diller, J. S., 1911, The types, modes of occurrence, and important deposits of asbestos in the United States: U. S. Geological Survey, Bulletin, no. 470, p. 507-512.

con't

Ferland, V. R., 1953, The economic development of the asbestos industry in Vermont: Unpublished Master's thesis, University of Vermont, Burlington, VT.

Frondel, Clifford, 1946, Minerals from a Vermont asbestos quarry: Rocks and Minerals, v. 21, no. 8, p. 490-491.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Keith, S. B. and Bain, G. W., 1932, Chrysotile asbestos: Economic Geology, v. 27, no. 2, p. 109-188.

Kemp, J. F., 1901, Notes on the occurrence of asbestos in Lamoille and Orleans Counties: Mineral Resources of the United States, U. S. Geological Survey, Mineral Resources of the United States, p. 862-865.

Kemp, J. F., 1901, A new asbestos region in northern Vermont (abs.): Science, n.s., v. 14, p. 773-774, also Am. Geol., v. 28, p. 330.

Kemp, J. F., 1902, A new asbestos region in northern Vermont (abs.): N. Y. Academy of Science, Annual Report, v. 14, p. 140-141.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1921, Mineral resources of Vermont: Vermont State Geologist, 12th Report (1919-1920), p. 299-326, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Perkins, G. H., 1930, Minerals of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 151-178, SGL, VSL.

Perkins, G. H., 1930, Mineral resources of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 253-259, SGL, VSL.

Richardson, C. H., 1910, Asbestos in Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 315-330, SGL, VSL.

Supplement

Barton, W. R. and Ratte', C. A., 1976, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 7 p., SGL.

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

White, D. H., Jr., and Ratte', C. A., 1979, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, 1978-1979, v. 2, 7 p., SGL.

SGL--Available at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Bain, G. W., 1934, Serpentinization, origin of certain asbestos, talc, and soapstone deposits: Economic Geology, v. 29, no. 4, p. 397-400.

Bain, G. W., 1942, Vermont talc and asbestos deposits: Newhouse, W. H., ed., Ore deposits as related to structural features: Princeton, NJ, Princeton University Press, p. 255-258.

Bain, G. W., 1969, Vermont talc and asbestos deposits: Newhouse, W. H., ed., Ore deposits as related to structural features: New York, NY, Hafner Pub., Inc., p. 255-258.

Burmeister, H. L., 1963, Mining and milling methods and costs, Eastern Magnesia Talc Co., Johnson Mine, Johnson, Vermont: U. S. Bureau of Mines, Information Circular no. 8142, 42 p.

Chidester, A. H., 1953, Geology of the talc deposits, Sterling Pond area, Stowe, Vermont: U. S. Geological Survey, Miscellaneous Field Studies Map, MF-11, SGL.

Chidester, A. H., 1959, Steatitization of serpentinite bodies in north-central Vermont: Unpublished Ph.D. thesis, University of Chicago, Chicago, IL.

Chidester, A. H., 1962, Petrology and geochemistry of selected talc-bearing ultramafic rocks and adjacent country rocks in north-central Vermont: U. S. Geological Survey, Professional Paper, no. 345, 207 p., SGL.

Chidester, A. H., 1968, Evolution of the ultramafic complexes of northwestern New England: Zen, E-an, White, W. S., Hadley, J. B., Thompson, J. B., Jr., eds., Studies of Appalachian geology, northern and maritime: New York and London, Interscience Publishers, John Wiley and Sons, chapter 26.

Chidester, A. H., Billings, M. P., and Cady, W. M., 1951, Talc investigations in Vermont: U. S. Geological Survey, Circular no. 95, Preliminary Report, 33 p., SGL.

Chidester, A. H., Stewart, G. W., and Morris, D. C., 1952, Geologic map of the Barnes Hill talc prospect, Waterbury, Vermont: U. S. Geological Survey, Miscellaneous Field Studies Map, MF-7, SGL.

Chidester, A. H., Stewart, G. W., and Morris, D. C., 1952, Geologic map of the Rosseau talc prospect, Cambridge, Vermont: U. S. Geological Survey, Miscellaneous Field Studies Map, MF-8, SGL.

Cline, L. B., 1960, The origin of talc at Johnson, Vermont, and the geology of its occurrence: Unpublished Master's thesis, University of Vermont, Burlington, VT, 99 p.

Coleman, L., 1835, Soapstone (in the Green Mountains of Vermont): American Journal of Science, v. 28, p. 370-371.

Dewey, Chester, 1822, Notice of crystallized steatite and ores of iron and manganese: American Journal of Science, v. 5, p. 249-251.

SGL--Available for use at the Office of the State Geologist, Montpelier, VT.

DuClos, K. F. and Thresher, M. C., ed., 1976, The history of Braintree, Vermont, v. II, 1883-1975: Montpelier, VT, Capital City Press, p. 47-50, SGL.

Forbes, W. C., Jr., 1967, The system talc-minnesotaite (abs.): Dissertation Abstracts International, section, B. Science and Engineering, v. 28, no. 1, p. 233B.

Gillson, J. L., 1927, Origin of the Vermont talc deposits with a discussion on the formation of talc in general: Economic Geology, v. 22, no. 3, p. 246-287.

Haig, George, 1963, Slick, hot, and handy (soapstone): Vermont Life, v. 18, no. 2, p. 13-14, VHL, VSL.

Hitchcock, C. H., 1860, On the so-called talcose schist of Vermont: American Association for the Advancement of Science, Proceedings, v. 13, p. 321-329.

Jacobs, E. C., 1914, Talc and talc deposits of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 382-429, SGL, VSL.

Jacobs, E. C., 1916, The talc and serpentine deposits of Vermont: Vermont State Geologist, 10th Report (1915-1916), p. 232-280, SGL, VSL.

Jacobs, E. C., 1918, Progress in talc production: Vermont State Geologist, 11th Report (1917-1918), p. 148-157, SGL, VSL.

Jacobs, E. C., 1921, Progress in talc production: Vermont State Geologist, 12th Report (1919-1920), p. 101-113, SGL, VSL.

Jacobs, E. C., 1934, Mineral resources of the state of Vermont: Vermont State Geologist, 19th Report (1933-1934), p. 3-36, SGL, VSL.

Jacobs, E. C., 1940, Mineral resources of the state of Vermont: Vermont State Geologist, 22nd Report (1939-1940), p. 5-67, SGL, VSL.

Marsters, V. F., 1905, Petrography of the amphibolite, serpentine, and associated asbestos deposits of Belvidere Mountain, Vermont: Geological Society of America, Bulletin, v. 16, p. 419-446.

Orton, V., 1952, Talcum powder under our mountains, the story of Vermont's Eastern Magnesia Talc Company: Vermont Life, v. 6, no. 2, p. 34-41, VHL, VSL.

Perkins, G. H., 1904, Mineral resources of the state of Vermont: Vermont State Geologist, 4th Report (1903-1904), p. 22-66, SGL, VSL.

Perkins, G. H., 1908, Vermont resources: Vermont State Geologist, 6th Report (1907-1908), p. 1-57, SGL, VSL.

Perkins, G. H., 1910, Mineral resources of Vermont: Vermont State Geologist, 7th Report (1909-1910), p. 331-352, SGL, VSL.

SGL--Available for use at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Perkins, G. H., 1912, Mineral resources of Vermont: Vermont State Geologist, 8th Report (1911-1912), p. 247-269, SGL, VSL.

Perkins, G. H., 1914, The mineral resources of Vermont: Vermont State Geologist, 9th Report (1913-1914), p. 430-439, SGL, VSL.

Perkins, G. H., 1923, Mineral resources of Vermont: Vermont State Geologist, 13th Report (1921-1922), p. 329-338, SGL, VSL.

Perkins, G. H., 1924, Mineral resources of Vermont: Vermont State Geologist, 14th Report (1923-1924), p. 344-351, SGL, VSL.

Perkins, G. H., 1927, Mineral resources of Vermont: Vermont State Geologist, 15th Report (1925-1926), p. 264-271, SGL, VSL.

Perkins, G. H., 1929, Mineral resources of Vermont: Vermont State Geologist, 16th Report (1927-1928), p. 382-386, SGL, VSL.

Perkins, G. H., 1930, Minerals of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 151-178, SGL, VSL.

Perkins, G. H., 1930, Mineral resources of Vermont: Vermont State Geologist, 17th Report (1929-1930), p. 253-259, SGL, VSL.

Radinsky, Leonard and Stifel, P. B., 1958, The geology of the Waterville talc deposits: Unpublished Senior thesis, Cornell University, Ithaca, NY, 54 p.

Weiss, Benjamin, 1961, Comparative study of some Vermont talc deposits: Unpublished Master's thesis, University of Michigan, Ann Arbor, MI.

Wenner, D. B., 1976, Geologic feasibility of talc and serpentine bodies from the Appalachian Mountain region of eastern United States with regard to siting of radioactive-waste repositories: Part I--Additional conclusions, Part II--A field investigation of talc and serpentinite deposits: A supplementary report, Union Carbide Corporation, NTIS #4496, Y/OW1/SUB-4496/2.

Zodac, Peter, 1940, A talc quarry near Chester, Vermont: Rocks and Minerals, v. 15, no. 11, p. 369-371.

SGL--Available for use at the Office of the State Geologist, Montpelier, VT.
VHL--Available at the Vermont Historical Society Library, Montpelier, VT.
VSL--Available at the Vermont State Library, Montpelier, VT.

Barton, W. R. and Ratte', C. A., 1976, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 7 p., SGL.

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Bitar, R. F. and Armstrong, M. K., 1982, Mineral resources of Bread Loaf RARE II further planning area, Addison and Washington Counties, Vermont: U. S. Department of the Interior, Bureau of Mines, Open-File Report, MLA-65-82, 15 p., SGL.

Chidester, A. H., Engel, A. E. J., and Wright, L. A., 1964, Talc resources of the United States: U. S. Geological Survey, Bulletin, no. 1167, p.48-49, SGL.

Seymour, B. O., 1977, Geology of the talc mine at East Johnson, Vermont: Unpublished Master's thesis, Queens College (CUNY), Flushing, NY.

White, D. H., Jr. and Ratte, C. A., 1979, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, 1978-1979, v. 2, 7 p., SGL.

SGL--Available for use at the Office of the State Geologist, Montpelier, Vermont.

The Uranium Provinces

Knowledge of the existence of anomalous radioactivity in various geologic settings in Vermont dates back to the early 1950's. Reconnaissance surveys of Vermont's current and abandoned quarries and mines, and old mineral prospects conducted by the U. S. Geological Survey in cooperation with the U. S. Atomic Energy Commission (McKeown, 1951, Grauch and Zarinski, 1976, and U.S.A.E.C.-U.S.G.S. report RME-4106 TID UC-51, 1969) confirmed the presence of anomalous radioactivity and in some cases uranium mineralization at several localities. A sporadic search for uranium and other radioactive minerals continued through the 1960's and 1970's, the most noted being that of the National Uranium Resource Evaluation program which is being conducted by the federal government (ERDA now DOE).* In recent years (1978-1979) private uranium firms started to explore in Vermont. Discoveries of ore grade mineralization in Precambrian terrane of southern Vermont prompted extensive land leasing for exploration and mining rights in the vicinity of Jamaica, Vermont. Citizen concern developed into well organized opposition to exploration, mining and milling of radioactive minerals in Vermont. Restrictive legislation was passed in 1980 that discouraged industry from further exploratory work in Vermont.

The Sedimentary Province

Uranium and phosphate mineralization is known to coexist in Franklin and Chittenden Counties. Uranium is present in a uranophosphate mineral, hydroxylapatite, where uranium substitutes for calcium in the mineral structure. The mineral occurs in clasts and as cement in an

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*ERDA = Energy Research and Development Administration
DOE = Department of Energy

intraformational breccia-conglomerate in the Cambrian Clarendon Springs Formation. The Clarendon Springs Formation extends (in western Vermont) from the Canadian border at Highgate to Bennington.

Radioactive anomalies have been identified in the Clarendon Springs Formation by ground surveys at Highgate, Milton and Shelburne. Samples collected from the anomalous rock at Highgate and Milton have been analyzed for uranium, thorium and phosphate content:

HIGHGATE	MILTON
U_3O_8 = 317 ppm	U_3O_8 = 0.04%
ThO_2 = 34 ppm	ThO_2 = 9 ppm
P_2O_5 = 25.64%	P_2O_5 = 16.98%

In the winter of 1969-1970, Rio Algom, a Canadian mining firm, conducted a limited (2 holes) core drilling program on the Highgate anomaly after drilling several holes on the same anomaly in Canada. The uranium analyses on several samples representing 756' of core produced results ranging from 0.02 lbs/ton to 0.46 lbs/ton. At the time this was considered to be considerably below ore grade.

An aerial radiometric survey conducted in 1964 by the U. S. Geological Survey in cooperation with the U. S. Atomic Energy Commission (Popenoe, 1964), covered portions of southern Vermont. This survey identified radioactively anamalous areas (see Ratte' and Vanecek, 1980, Radioactive Anomaly Map of Vermont).

The Texas Instruments Corporation flew an airborne radiometric survey in 1976 for the National Uranium Resource Evaluation program (NURE). This survey covered all of Vermont (as well as New York and other New England states). The Milton and Shelburne anomalies as well as anomalies near Mechanicsville and Monkton Ridge were detected, however, the Highgate anomaly was not picked up by this survey. To the south in the Vermont

Valley anomalies were located near Tinmouth and Danby by both aerial surveys (Popenoe, 1964 and Texas Instruments, Inc., 1976). These anomalies are associated with the Clarendon Springs Formation or similar lithologies (Dunham Formation).

The U.S.A.E.C. report (RME-4106) indicates anomalies exist at the Lyon Hill* Lead-Zinc prospect in Leicester and at the Brandon "Silver" mine** in Brandon. These were not detected by the Texas Instruments airborne survey but are believed to be located in Clarendon-Dunham lithologies.

The Crystalline Province

Vein-type. Vein-type occurrences within strata-bound sulfide deposits are known to exist in Vermont's metamorphic terrane. The old Udall Copper mine at Wolcott, first reported by Butler, et. al. (1962), is located in Cambrian-Ordovician schist of the Stowe Formation. A sample from this site was analyzed for the U.S.A.E.C. (in RME-4106) and reported to contain 0.06% uranium. Anomalous radioactivity is reported (in RME-4106) at the Old Boston Copper mine in West Berkshire, and at the Sherbrook Lead prospect*** in Newport. No analytical data is available from these last two reported "probably vein-type" occurrences in Cambrian-Ordovician schist. These localities were not detected by the Texas Instruments, Inc. airborne survey.

Precambrian. The first report of anomalous radioactivity in Vermont's Precambrian terrane (located in the central Green Mountains

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*Location not well documented.

**Not the same as the Brandon lead-zinc prospect in Forestdale but located on the hill (elev. 1209') east of Sugar Hollow (see U. S. G. S. 7 1/2-minute quadrangle Brandon, Vermont).

***Location not well documented.

from Lincoln south to the Massachusetts border in Stamford, Readsboro and Whitingham) was at Snow Valley, in Winhall. This anomaly was reported in the U.S.A.E.C.-U.S.G.S. reconnaissance report RME-4106, TID UC-51. Analytical data is available (McHone and Wagener, 1980). This anomaly was not detected by the 1976 airborne survey conducted for the NURE program by Texas Instruments, Inc., however, the anomaly does show up on the 1964 U.S.G.S. aeroradioactivity survey (Popenoe, 1964).

Uranium mineralization in Vermont's Precambrian terrane (all rock types are metamorphic and undifferentiated--known as the Mt. Holly complex) is stratigraphically and structurally controlled having been mobilized and reconcentrated during subsequent Paleozoic metamorphic events. The mineralogy of these Precambrian occurrences is not well known and mineral associations vary from place to place. Radioactive anomalies are associated with quartz-tourmaline pegmatite in micaceous quartzites and gneissoid feldspathic quartzites. Biotite and graphite-rich zones in quartzite also show anomalously high radioactivity. Dark, schist-like occurrences of fine-grained biotite and tourmaline, probably resulting from hydrothermal alteration, in sheared quartzite are often highly radioactive.

Samples collected in the vicinity of Ludlow (Okemo) Mountain in the towns of Mt. Holly, Ludlow and Weston were analyzed in the fall of 1979 for the Vermont Division of Geology and Earth Resources, Agency of Environmental Conservation. The results are as follows:

- Okemo Mt. (top near fire tower) 3000 ppm or 0.397% U.
- Grant Brook (near South Mt., Ludlow)

  1. elev. 2105' 105 ppm U.
  2a. elev. 2040' 750 ppm or 0.075% U.
  2b. elev. 2040' 520 ppm or 0.06% U.

- Route 155 (approx. 1 mile north of Rte. 155-Rte. 100 intersection) 28 ppm U.

The Grant Brook anomaly was detected by the Texas Instruments, Inc., aerial survey and the Ludlow (Okemo) Mountain anomaly by the U.S.G.S. airborne survey (Popenoe, 1964).

Both aeroradiometric surveys detected additional anomalies in both Precambrian and Paleozoic terranes. Ground checks of these anomalies have been conducted and samples collected for assay by the NURE program geologists. The results have been published in reports listed in the uranium bibliography (McHone and Wagener, 1980, and Field and Truesdell, 1980).

The Granitic Province

Anomalous radioactivity and the potential for uranium occurrences exist in granitic rocks and associated pegmatites of the Devonian New Hampshire plutonic series (northeastern Vermont), and the Jurassic-Cretaceous White Mountain plutonic series (Mt. Ascutney in Brownsville, Granite Hill in Cuttingsville, Barber Hill in Charlotte, and Monadnock Mt. in Lemington). The Popenoe (1964) aeroradiometric survey recorded an anomaly at Granite Hill and Mt. Ascutney, and one in the Devonian pluton at Bellows Falls-Walpole, New Hampshire. No anomaly was detected by the Texas Instruments, Inc., airborne survey at Barber Hill. Neither survey covered the area of Monadnock Mt. in far northeastern Vermont.

Barton, W. R. and Ratte', C. A., 1976, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 7 p., SGL.

Barton, W. R. and Ratte', C. A., 1977, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook, v. 2, 8 p., SGL.

Butler, A. P., Jr., Finch, W. I., and Twenhofel, W. S., 1962, Epigenetic uranium in the United States (exclusive of Alaska and Hawaii): U. S. Geological Survey, Min. Invest. Res. Map, MR-21.

Cook, J. R., 1981, Albany $1^{o}x2^{o}$ NTMS area, Connecticut, New Hampshire, Massachusetts, New York and Vermont--Supplemental Data Report--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-79-146-10S) (GJBX-107-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC09-76SR00001, 17 p., SGL.

Cook, J. R., 1981, Glens Falls $1^{o}x2^{o}$ NTMS area, New Hampshire, New York and Vermont--Supplemental Data Report--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-79-146-3S) (GJBX-70-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC09-76SR00001, 17 p., SGL.

Cook, J. R., 1981, Lake Champlain $1^{o}x2^{o}$ NTMS area, New York, Vermont, and New Hampshire--Data Report (abbreviated)--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-81-146-2) (GJBX-108-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC09-76SR00001, 17 p., SGL.

Cook, J. R., 1981, Lake Champlain $1^{o}x2^{o}$ NTMS area, New York, Vermont, and New Hampshire--Supplemental Data Report--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-81-146-2S) (GJBX-282-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC09-7600001, 17 p., SGL.

Cook, J. R., 1981, Lewiston $1^{o}x2^{o}$ NTMS area, Maine, New Hampshire, and Vermont--Supplemental Data Report--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-80-146-18S) (GJBX-348-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC0900001, 18 p., SGL.

Cook, J. R. and Koller, G. R., 1980, Lewiston $1^{o}x2^{o}$ NTMS area, Maine, New Hampshire, and Vermont--Data Report (Abbreviated)--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-80-146-18) (GJBX-14-81): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract DE-AC09-76SR00001, 17 p., SGL.

Cooper, M., 1958, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States: Geological Society of America, Special Paper, no. 67, part 5, eastern states, 8 v., 472 p.

Field, M. T. and Truesdell, D. B., 1980, Uranium resource evaluation, Albany quadrangle, Massachusetts, New York, Connecticut, Vermont, and New Hampshire (preliminary report): Work performed under Bendix Field Engineering Corp., Grand Junction Operations, contract DE-AC-13-76GJ01664, prepared for the U. S. Department of Energy, Grand Junction, CO, PGJ(81), SGL.

con't

Grauch, R. I. and Zarinski, Katrin, 1976, Generalized descriptions of uranium-bearing veins, pegmatites, and disseminations in non-sedimentary rocks, eastern United States: U. S. Geological Survey, Open-File Report, no. 76-582, SGL.

Greenberg, J. K., Hauck, S. A., Ragland, P. C., and Rogers, J. J. W., 1977, A tectonic atlas of uranium potential in the crystalline rocks of the eastern United States: U. S. Department of Energy, Open-File Report, GJBX-69(77), microfiche, 94 p., SGL.

Jones, P. L. and Price, Van, 1979, Orientation study data release VII Wolcott, Vermont, area--Savannah River Laboratory hydrogeochemical and stream sediment reconnaissance, National Uranium Resource Program (DPST-78-141-2)(GJBX-43-79): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract AT(07-2)-1, 28 p., SGL.

Koller, G. R., 1979, Albany $1^{\circ}x2^{\circ}$ NTMS area, Connecticut, Massachusetts, New Hampshire, New York, and Vermont--Data Report--National Uranium Resource Evaluation Program, E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract AT(07-2)-1, 143 p., SGL.

Koller, G. R., 1979, Glens Falls $1^{\circ}x2^{\circ}$ NTMS area, New Hampshire, New York, and Vermont--Data Release--National Uranium Resource Evaluation Program, hydrogeochemical and stream sediment reconnaissance (DPST-79-146-3)(GJBX-44-79): E. I. DuPont de Nemours and Co., Savannah River Laboratory, Aiken, SC, for U.S.D.O.E. contract AT(07-2)-1, 143 p., SGL.

McHone, J. G. and Wagener, H. D., 1980, Distribution of uranium and thorium in central New England and northeastern New York (abs.): Geological Society of America, Northeastern Section, 15th Annual Meeting, Abstracts with Program, v. 12, no. 2, p. 73, SGL.

McHone, J. G. and Wagener, H. D., 1980, Uranium resource evaluation, Glens Falls quadrangle, New York, Vermont, and New Hampshire: Work performed under Bendix Field Engineering Corp., Grand Junction Operations, contract DE-AC13-76GJ01664, subcontract no. 78-115-S, prepared for the U. S. Dept. of Energy, Grand Junction, CO, SGL.

McKeown, F. A., 1951, Reconnaissance of radioactive rocks of Vermont, New Hampshire, Connecticut, Rhode Island, and southeastern New York: U. S. Geological Survey Report, TEI-67, prepared for the U. S. Atomic Energy Commission, Oak Ridge, TN, 48 p., SGL.

Mory, P. C., 1981, Mineral resources of Bristol Cliffs Wilderness Areas, Addison County, Vermont: U. S. Department of the Interior, Bureau of Mines, Open-File Report, MLA 18-81, 15 p., SGL.

Ratte', C. A. and Vanecek, D. M., 1980, Radioactivity map of Vermont: Vermont Division of Geology and Earth Resources, Open-File Report, no. 1980-1, scale 1:250,000, 11 p., SGL.

Rogers, J. J. W., Ragland, P. C., Nishimori, R. K., Greenberg, J. K., and Hauck, S. A., 1978, Varieties of granitic uranium deposits and favorable exploration areas in the eastern United States: Economic Geology, v. 73, p. 1539-1555.

con't

Sabin, A. E. and Jones, J. B., 1982, Mineral resources of Devils Den RARE II further planning area; Rutland and Windsor Counties, Vermont: U. S. Department of the Interior, Bureau of Mines, Open-File Report, MLA-34, 16 p., SGL.

Texas Instruments, Inc., 1976, Airborne geophysical survey of a portion of New England: Prepared for the U. S. Energy Research and Development Administration, Grand Junction Office, contract E(05-1)-1666 and E(05-1)-1667, GJO-1666-1, SGL.

U. S. Atomic Energy Commission, Division of Raw Materials, 1969, Preliminary reconnaissance for uranium in Connecticut, Maine, Massachusetts, New Jersey, New York, and Vermont, 1950-1955: U. S. Atomic Energy Commission, Division of Raw Materials, U. S. Geological Survey, RME-4106, TIC UC-51, SGL.

U. S. Department of Energy, 1980, An assessment report on uranium in the United States of America: GJO-80-111, 150 p.

White, Jr., D. H. and Ratte', C. A., 1979, The mineral industry of Vermont: U. S. Bureau of Mines, Minerals Yearbook 1978-1979, v. 2, 7 p., SGL.

SUPPLEMENT TO URANIUM BIBLIOGRAPHY

*Fay, W. M., Sargent, K. A., and Cook, J. R., 1982, Data report--New England--National Uranium Resource Evaluation Program, Hydrogeochemical and stream sediment reconnaissance (DPST-81-146-27)(GJBX-107-82): E. I. DuPont de Nemours and Co., for U.S.D.O.E., contract DE-AC09-76SR00001, 36 p., SGL.

Field, M. T. and Truesdell, D. B., 1982, National uranium resource evaluation, Albany quadrangle, Massachusetts, New York, Connecticut, Vermont, and New Hampshire: Bendix Field Engineering Corp., Grand Junction Operations, for U.S.D.O.E., contract DE-AC07-76GJ01664, PGJ/F-104, 46 p., SGL.

Harrison, D. K., 1981, Mineral resources of the Lye Brook Wilderness Areas, Bennington and Windham Counties, Vermont: U. S. Department of the Interior, Bureau of Mines, Open-File Report, MLA-17-81, 21 p., SGL.

Karfunkel, B. S., 1983, Geology and mineral resources of the Baltimore, Boston, Lake Champlain, and Providence 1°x2° NTMS quadrangles--National Uranium Resource Evaluation Program--Hydrogeochemical and stream sediment reconnaissance (DPST-81-144-9): E. I. DuPont de Nemours and Co., for U.S.D.O.E. contract GJBX-8(83), 127 p., microfiche, SGL.

McHone, J. G. and Wagnener, H. D., 1982, National uranium resource evaluation, Glens Falls quadrangle, New York, Vermont, and New Hampshire: Bendix Field Engineering Corp., Grand Junction Operations, for U.S.D.O.E., contract DE-AC07-76GJ01664, report no. PGJ/F-025(82), 31 p., SGL.

McKeown, F. A. and Kelmic, Harold, 1953, Reconnaissance for radioactive materials in northeastern United States during 1952: Prepared by the U. S. Geological Survey for the U. S. Atomic Energy Commission, Technical Information Service, Oak Ridge, TN, Report no. TEI-317-A, microfiche, SGL.

Overstreet, W. C., 1967, the geologic occurrence of monazite: U. S. Geological Survey, Professional Paper, no. 530, p. 265-266, SGL.

Ratte', C. A., 1979, A uranium province map for Vermont (abs.): Green Mountain Geologist, v. 5, no. 4, SGL.

Ratte', C. A., 1982, Mineral resource provinces of Vermont: A current look at Vermont's mineral resources potential and mineral industries: Vt. Div. Geol. and Earth Res., Open-File Rept., no. 1982-1, scale 1:250,000, SGL.

con't

Rouse, G. E., 1979, "Other" uraniferous phosphate resources of the United States: DeVoto, R. H., ed., et al., Uraniferous phosphate resources and technology and economics of uranium recovery from phosphate resources, United States and free world, p. 249-329, Report number GJBX-110(79), available from Earth Science.

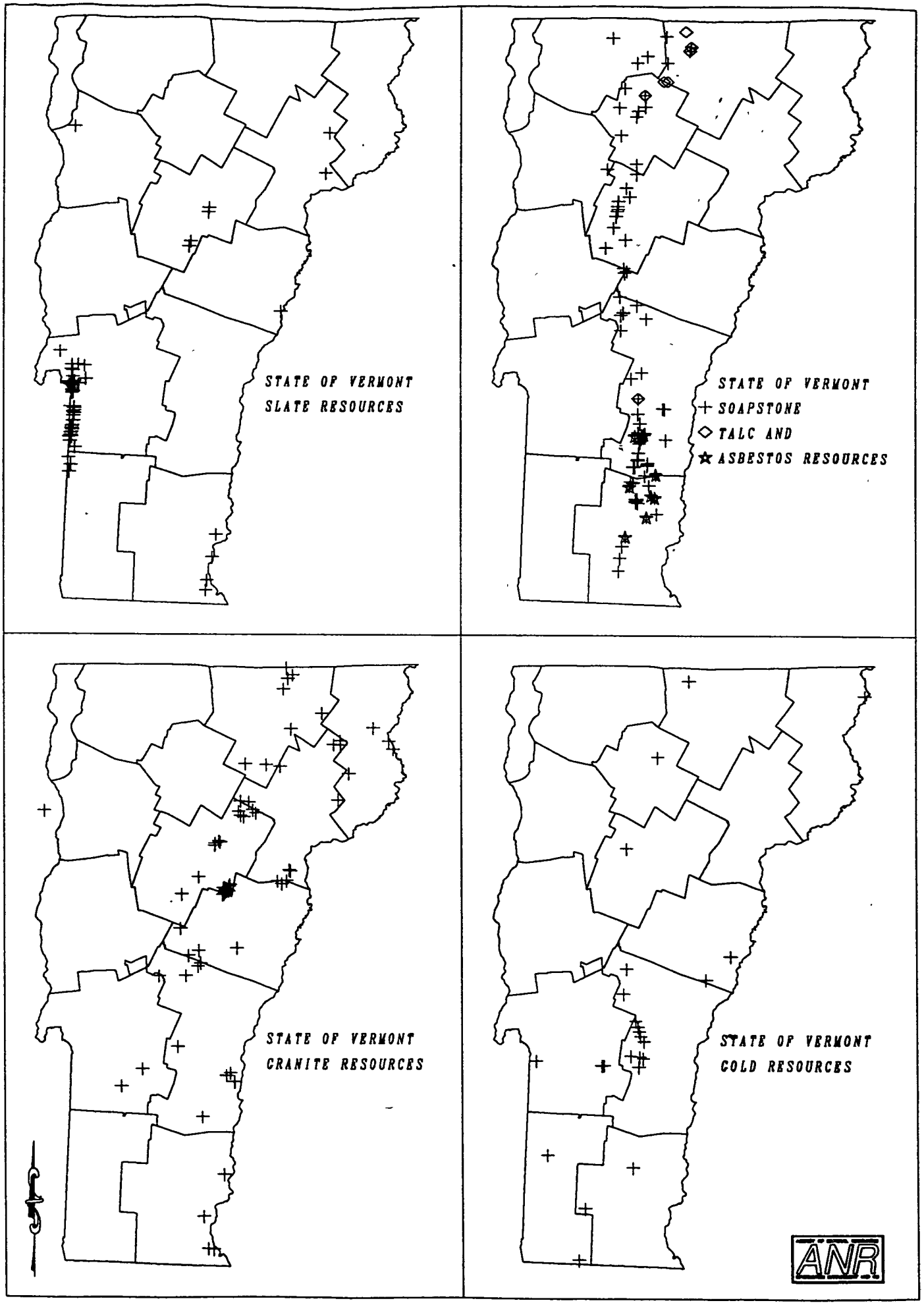
Texas Instruments, Inc., 1982, Interpretation of hydrogeochemical and stream sediment reconnaissance data, Glens Falls quadrangle, New York, Vermont and New Hampshire: Report no. GJD-031-82, microfiche, SGL.

Union Carbide Corp., 1982, Hydrogeochemical and stream sediment reconnaissance basic data for Elmira, Binghamton, and Albany quadrangles, New York, Massachusetts, Vermont, and New Hampshire: Uranium Resource Evaluation Proj., Nuclear Division, GJBX-83(82), K/UR-438, 81 p., microfiche, SGL.

Union Carbide Corp., 1982, Hydrogeochemical and stream sediment reconnaissance basic data for Glens Falls quadrangle, New York, Vermont, and New Hampshire: Uranium Resource Evaluation Proj., Nuclear Division, GJBX-86(82), K/UR-441, 31 p., microfiche, SGL.

Union Carbide Corp., 1982, Hydrogeochemical and stream sediment reconnaissance basic data for Ogdensburg and Lake Champlain quadrangles, New York and Vermont: Uranium Resource Evaluation Proj., Nuclear Division, GJBX-87(82), K/UR-442, 76 p., microfiche, SGL.

SGL--Available for use at the Office of the State Geologist, Montpelier, Vermont.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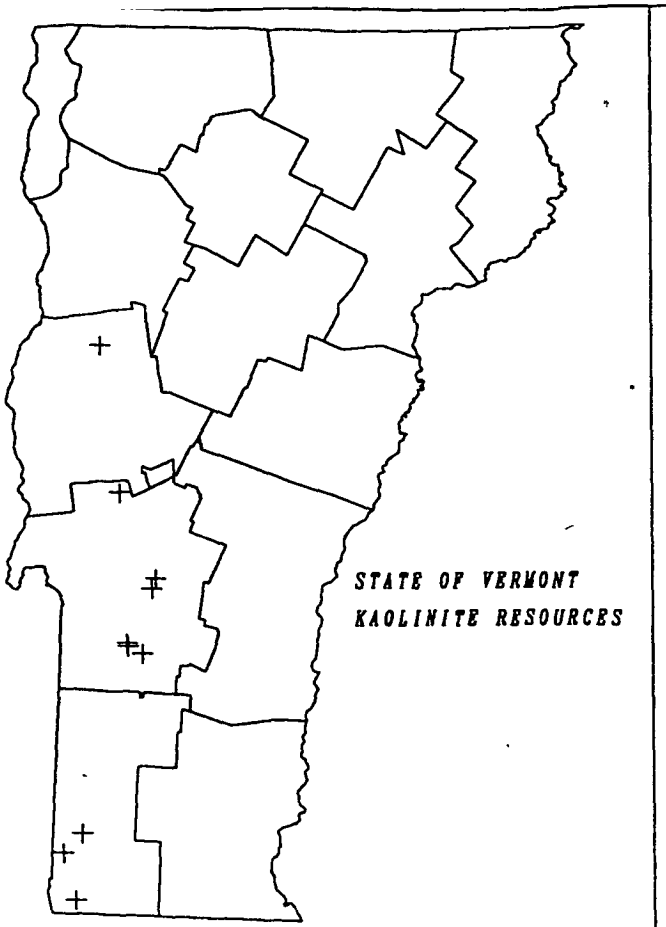
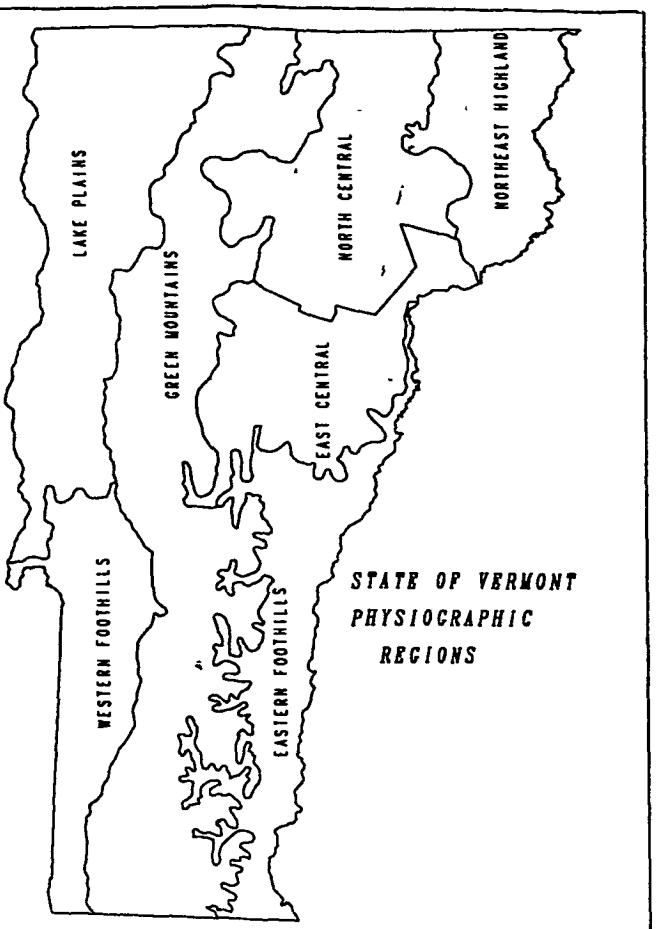
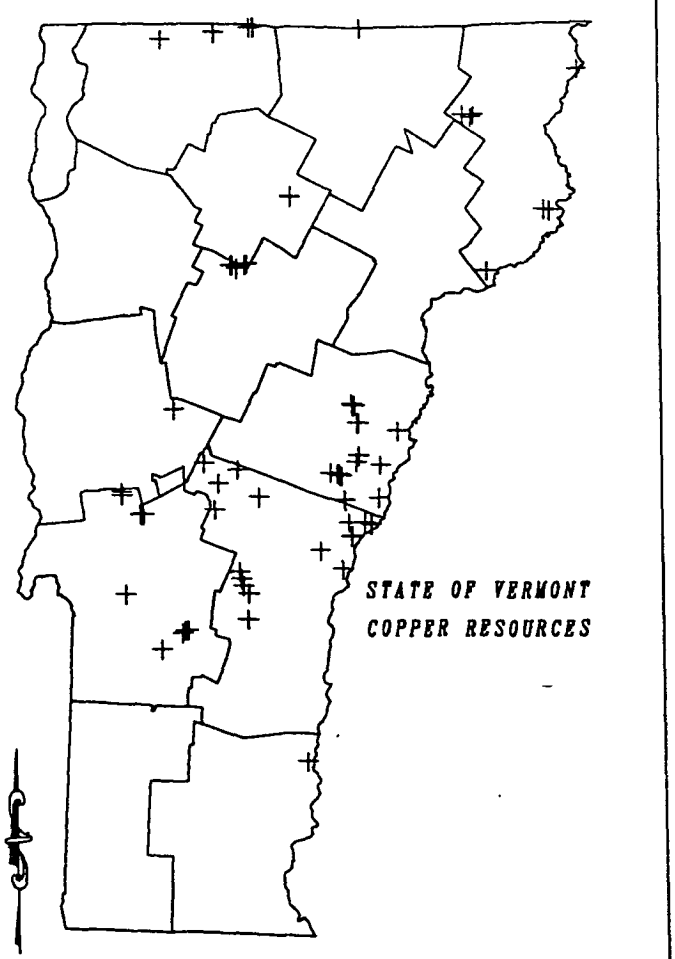
GOLD RESOURCES
ANR



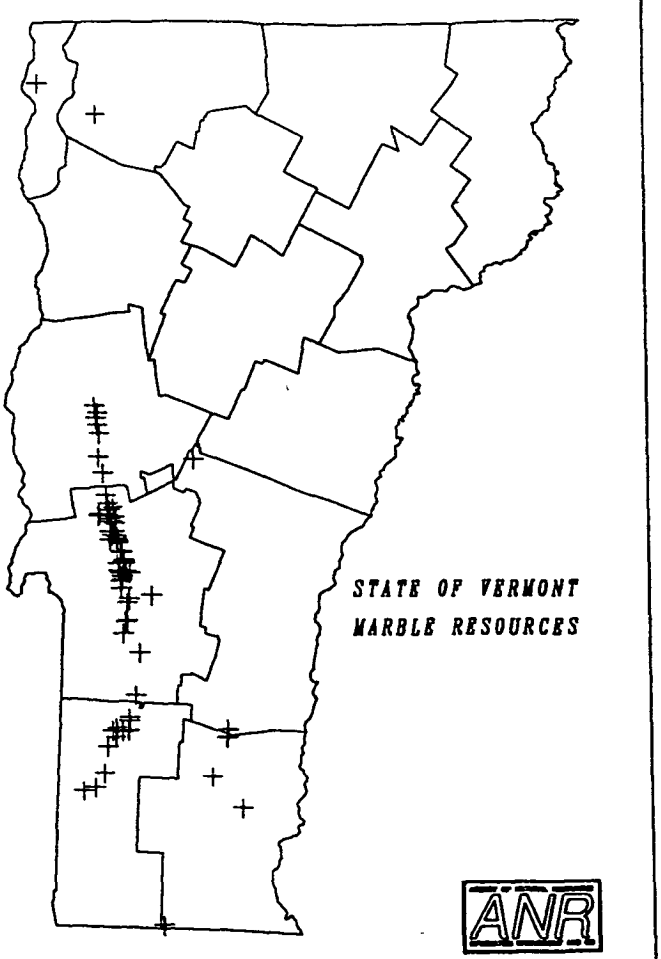
STATE OF VERMONT
KAOLINITE RESOURCES



STATE OF VERMONT
PHYSIOGRAPHIC
REGIONS



STATE OF VERMONT
COPPER RESOURCES



STATE OF VERMONT
MARBLE RESOURCES

ANR