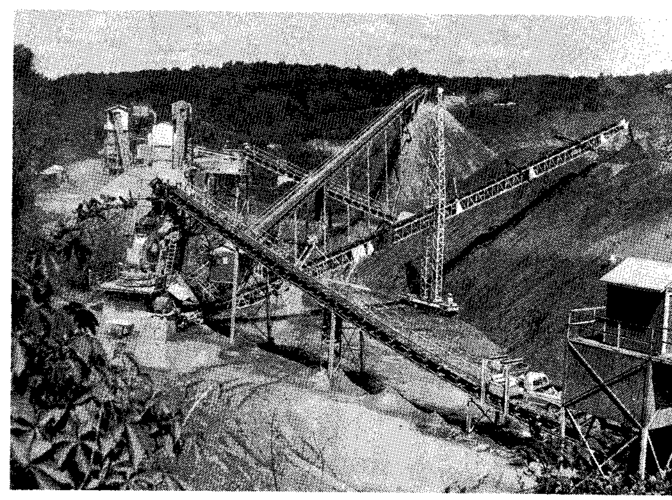
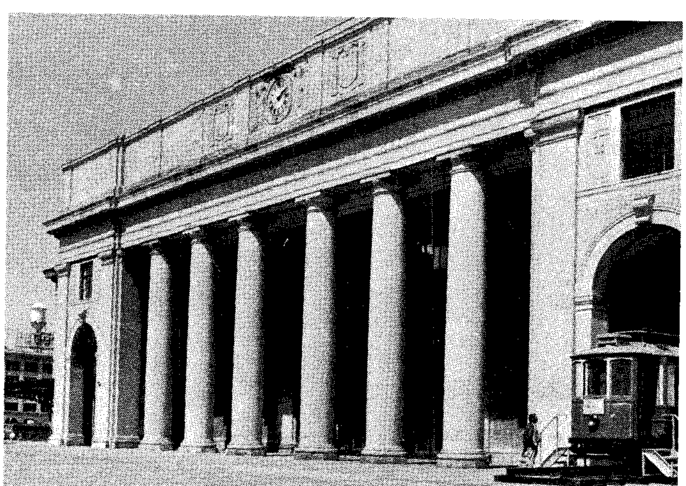
VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 62

MINERALS FOR VIRGINIA

Harry W. Webb and John P. Moore





COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
Robert C. Milici, Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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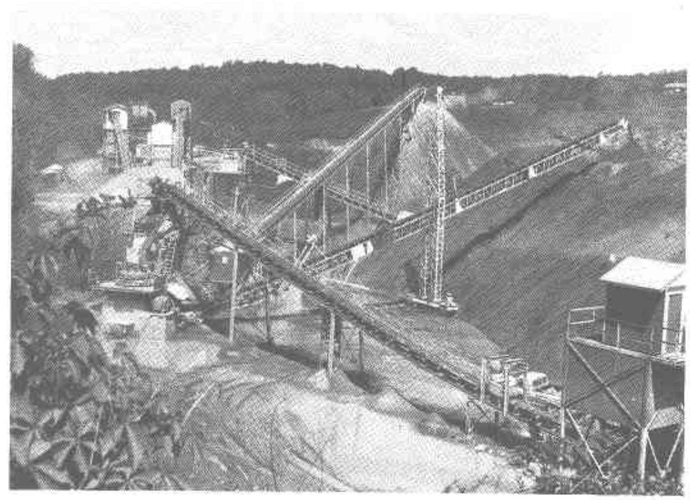

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Front cover: Clockwise from upper left — Location of potential resource; Extracting needed materials; Use for building construction; Reclaimed pit used for crops.

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DEPARTMENT OF MINES,
MINERALS AND ENERGY

Richmond, Virginia

O. GENE DISHNER, Director

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF PURCHASE AND SUPPLY
RICHMOND

1985

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ILLUSTRATIONS

TABLE

YOUR HOME AND THE MINERAL INDUSTRY[1]

The raw material for the majority of the material used in building your home was furnished by the mining industry.

The foundation is probably concrete (limestone, clay, shale, gypsum, and aggregate mining).

The exterior walls may be made of brick (clay mining) or stone (dimension stone mining).

The insulation in the walls may be glass wool (silica, feldspar, and trona mining) or expanded vermiculite (vermiculite mining).

The interior walls are usually wallboard (gypsum mining).

The lumber in the structure will be fastened with nails and screws (iron ore mining and zinc mining).

If the roof is covered with asphalt shingles, the filler in the shingles is from a variety of colored silicate minerals from mining.

Your fireplace is probably of brick or stone, lined with a steel box (iron ore mining).

Your sewer piping is made of clay or iron pipe (clay mining or iron ore mining). Your water pipe is of iron or copper pipe (iron ore mining and copper mining).

Your electrical wiring is of copper or aluminum (copper mining or bauxite mining).

Your sanitary facilities are made of porcelain (clay mining).

Your plumbing fixtures are made of brass (copper and zinc mining), or stainless steel (nickel and chrome mining).

Your gutters are of galvanized steel (iron ore mining and zinc mining).

The paint is manufactured with mineral fillers and pigments (from minerals obtained by mining).

Your windows are made of glass (trona, silica and feldspar mining).

Your door knobs, locks, and hinges are of brass or steel (copper, zinc, and iron ore mining).

And finally, your mortgage is written on paper made from wood or cloth fibers, but fibers filled with clay (clay mining).

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[1] Modified from *Mining Engineering*, January 1976. The foregoing examples were cited by F. T. Davis, Western Regional Vice President, Society of Mining Engineers.

IN APPRECIATION

The following assisted in the preparation of this report: James E. Fox, Virginia Aggregates Association Inc.; Robert C. Milici, Donald C. Le Van, Palmer C. Sweet, Mark P. Phillips, Division of Mineral Resources; William O. Roller and staff, Division of Mined Land Reclamation, David E. Jordan, Department of Taxation; Wayne Richards, Department of Highways and Transportation; Renaldo C. Jenkins, Air Pollution Control Board; Larry G. Lawson, Water Control Board; Christopher E. Loftus, Department of Labor and Industry; Harry D. Childress, Division of Mines; Henry C. Bernick, III, Marine Resources Commission; John R. Knight, Department of Housing and Community Development; John Hutchison, Division of Urban and Environmental Planning, University of Virginia; Rosser Payne, private consultant; Rich Renniger and Paula Burns, National Crushed Stone Association; and members of the various planning district commissions of the State.

The plant tours, given be numerous members of the Virginia Aggregates Association Inc., to acquaint the authors with extractive processes and equipment are gratefully acknowledged.

MINERALS FOR VIRGINIA

Harry W. Webb and John P. Moore

INTRODUCTION

Virginia is rich in minerals--a natural wealth. The welfare and economic progress of the Commonwealth has been largely dependent upon the discovery and production of rock and mineral resources since Colonial days. Mineral production in North America began with the settlement at Jamestown, where iron was produced as early as 1609. The types and amounts of minerals used have varied since then, largely in response to the economic development of the State and Nation. Today a variety of natural rock materials are extracted from mines, pits, and quarries across the State for many uses (Map in Pocket). The purpose of this report is to describe industrial mineral development of the State, exclusive of fuels and metals, in terms understandable to the general reader.

Virginia has a large and diverse mineral industry. In 1985 some 249 producers were engaged in providing valuable mineral commodities statewide. All of Virginia's counties have resources from which mineral commodities can be produced. There are some counties, however, in which minerals are not being extracted today. Production of industrial minerals in Virginia is a multimillion-dollar-a-year industry and in 1983, was valued at about $289,344,000.

Many raw mineral materials are mined from quarries and pits (Figures 1 and 2). These openings in the ground mean different things to a wide variety of people. To consumers, they are sources of much needed stone or other material for construction or manufacturing. To quarrymen, they are their workplace, their livelihood. To geologists, they are windows in the ground through which they can interpret the type and arrangement of rocks from which mineral resources are derived. To rockhounds, they are excellent places to collect prized specimens. To others they may be viewed as eyesores or environmental threats. Regardless of how they are viewed, *quarries and pits are the sources for products that are essential to the maintenance of our society*.

Our modern society benefits greatly from the development and production of mineral resources. Extraction of these resources, however, must be carried out in such a way as to minimize environmental degradation. Indeed, the price of a mineral product must contain the costs of reclamation. Future generations should not be made to bear the burden of cleaning up long-term environmental problems left by their predecessors.

Figure 1. Quarry operation with drilling rig preparing holes for blasting; in the background a loaded 35-ton truck is on the way to the crusher.

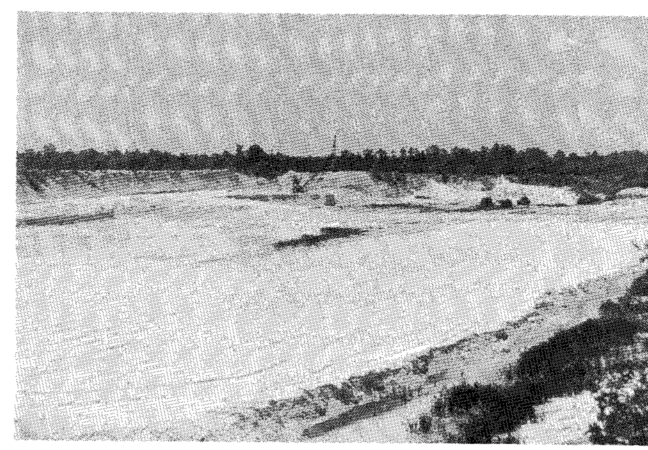

Figure 2. Drag-line crane (photo rear center) extracting sand and gravel from upper bench.

NEED FOR RESOURCES

Materials from quarries and pits are used for a variety of purposes, most importantly for the construction of shelter and the growing of food. Crushed stone, cement, sand, and gravel are the very foundation of the construction industry. Earth materials, such as sand, shale, limestone, and slate are the industrial raw materials used for the manufacturing of glassware, roofing materials, concrete, bricks, fertilizers, and chemicals.

Virginia is blessed with many types of mineral resources which have abundant uses (see List of

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RAW MATERIALS	PRODUCT USES
	Construction
Amphibolite, basalt, clay, diabase, dolomite, feldspar, gneiss, granite, gravel, greenstone, iron-oxide pigments, quartzite, gypsum, limestone, marble, oyster shells, phyllite, sand, sandstone, schist, shale, slate, vein quartz, vermiculite	• Building bricks, walls, foundation, insulation, roofing materials, windows, facing stone, hearths, light-weight and ornamental aggregate, concrete, cement • Bridges, driveways, sidewalks • Dams, riprap, jetties • Landscaping materials, golfcourses • Roads, railroad ballast, airport runways
	Agriculture
Clay, dolomite, granite, gypsum, limestone, marble, marl, sand, sandstone, vermiculite	• Feed supplements • Fertilizers • Insecticides • Potting materials • Poultry grits • Soil conditioners
	Manufacturing
Clay, diabase, dolomite, feldspar, gemstones, granite, gypsum, iron-oxide pigments, kyanite, limestone, quartzite, sand, sandstone, schist, shale, soapstone, talc, unakite, vermiculite aggregate	• Abrasives • Absorbents • Appliances • Cemetery monuments • Chemicals • Foundry linings • Glassware • Jewelry • Light-weight aggregate • Paints • Packing materials • Paper • Pottery • Refractory products • Toothpaste
	Pollution Abatement, Health, Safety
Clay, gravel, limestone, sand, sandstone	• Acid mine-water neutralization • Erosion control • Flu gas desulfurization • Mine safety dust • Sewage treatment • Water filtration and purification • Traction on ice and snow

Available Materials Not Being Used

Arsenopyrite, barite, bauxite, beryl, cobalt, columbium, copper, diatomaceous deposits, emery, gold, greensand, iron, kaolin, lead, manganese, mica, nickel, phosphate rock, pyrite, pyrrhotite, salt, silver, soapstone, tin, titanium, travertine, uranium, zinc

Virginia's Mineral Resources). The use of products from these resources is one important reason why the citizens of the Commonwealth have a high standard of living.

In recognition of the foregoing needs, the Virginia Legislature had placed in the *Code of Virginia* (Title 45.1, Chapter 16, Section 45.1-180.2,A) the following statement:

> "The General Assembly finds that the mining of minerals within the Commonwealth is an activity that makes a contribution to the standard of living of the citizens of the Commonwealth; and that it is in the public interest to insure the availability and orderly development of mineral resources now and in the future..."

ROLE IN STATE AND LOCAL ECONOMY

Economic Development

Production of rock and mineral products plays an important role in the state and local economy. Jobs, wages, taxes, and development of peripheral industries help to maintain and advance the standard of living across the State.

In 1983 about 4,000 persons were employed by quarry and pit operators. Related wages and salaries amounted to about $66,000,000. An individual quarry or pit contributes to the economy as employees purchase homes and shop in local stores and as mineral producers buy items such as fuel, electricity, trucks and office supplies from local businesses. Peripheral industries related to selling and repairing of mining and milling machinery may develop in the areas of quarries and pits. These aid the local economy by providing jobs and adding to the tax base. The total worth of extracted nonfuel products in 1982 was approximately $263,183,000 and by 1983, the worth had increased to about $289,344,000. Of 1983 values, approximately 55 percent was from crushed stone; 9 percent, sand and gravel; and 11 percent, lime.

Taxation

The mineral industry contributes to the tax base of state and local government. State taxes include corporation income tax, intangible personal property tax, and franchise and sales tax. Six percent of a corporation's Virginia income is taxable. Intangible property, as defined by the Virginia Legislature, includes stockpiles of processed extracted materials. Domestic stock corporations pay an annual franchise fee on their authorized capital stock. A three percent sales tax is also levied by the State on products sold. Unemployment and workers compensation insurance must also be paid to the State.

Local taxes are paid to either the county or city depending upon the quarry or pit location. These taxes can include real estate, motor vehicles, machinery and tools, sales, and utility. The real estate tax is generally levied from $5 - $50 per acre of reserve to be extracted for quarries, and $0.05 - $0.10 per acre for pits. Automobiles and trucks are valued by a recognized pricing guide and taxed as a percentage of this value. Machinery and tools are valued by means of depreciated cost or as a percentage of original capitalized cost. Additional sales tax of one percent can be levied by cities and counties. Many counties, cities, and towns tax electric, gas and water consumption and telephone service, real estate, tangible personal property, machinery, and tools.

The amount of taxation should be carefully levied by state and local government. Marginal operations may be forced out of business by excessive taxation. High taxes may discourage the search for additional reserves in excess of annual needs. Items exported must be priced to compete with those in nations were the cost of the products is subsidized or controlled.

To encourage investment in the extractive industry the U. S. government allows tax reductions for depletion of natural materials on an annual basis such as sand and gravel at 5 percent and most metals at 15 percent.

PROBLEMS IN DEVELOPING MINERAL RESOURCES

Location of potential resource areas, exploration and development costs, public acceptance, land-use controls, fluctuating market prices, taxes, material depletion, and reclamation requirements are potential problems in developing and marketing mineral resources.

Exploration and Development

Quarries can only be located effectively where nature has concentrated suitable deposits. The best sites for quarries and pits are those places that have the highest quality materials, are the least costly to operate, and cause the least adverse environmental impact. As resources from the better sites are exhausted, and the demand for mineral products continues, somewhat less desirable locations have to be used. As a result, it commonly becomes progressively more expensive to produce a mineral commodity, and the customer pays more.

The identification of a commercially profitable mineral deposit may require expensive and extensive investigations by geologists. Because of the long time it takes to develop a new deposit, market conditions may not be favorable at time of initial production. To prepare for an extractive quarry plant, 5 to 30 million dollars may be needed to purchase the land, develop the site, and obtain the necessary equipment for extraction and processing. Sand and gravel pits cost less to develop than quarries. Processing techniques must be developed to minimize cost and to dispose safely of any waste materials.

The *Code of Virginia* (Title 45.1, Chapter 16, Section 45.1-180.2,C) contains the provision to require and encourage the proper control of mining so as to protect the health and property of citizens and the environment, while ensuring employment and the economic well-being of the State.

Public Acceptance and Planning

Public perception of extractive industries is often influenced by the nature of "past" operations. Of great concern are noise, vibration, dust, truck traffic, water and air pollution, and plant appearance. Today's operations are designed to conform with environmental regulations and to be more acceptable to the public. Special efforts may be needed to avoid damaging local water wells and streams.

Landowners should be involved in the initial planning phase of pit and quarry development so that they might help develop suitable plans for post-extraction use of their land. This approach allows landowners and nearby residents to plan for enhancement of land values after reclamation. Proper design negates most adverse environmental effects to an extraction site. Where these sites of quarries and pits are compatible with adjacent land use, the impact of extraction is lessened. Reclaimed sites may have potential for farming, recreation, water storage, industry, waste disposal, and forestry.

Mineral producers constantly deal with depletion of resources at sites of operations. In order to continue to operate, new material sources must be found as older deposits are exhausted.

Community leaders can assist in the orderly development of mineral resources by proper utilization of comprehensive planning and land-use controls, such as zoning. These controls should allow for the extraction of the known mineral resources before urbanization and for the reclamation of the site for other uses after the resources are exhausted. Land-use plans should include a market study of state and local mineral needs for extraction. Geologic studies are needed to locate potential mineral resources and to determine their suitability for current market demands. Such studies are performed by industry, federal government, and state geological surveys, e.g. the Virginia Division of Mineral Resources.

Marketing

Resources must be of commercial value to be extracted; enough material of sufficient quality must be present under mineable conditions. In general, production of lower-grade materials disturbs more land, creates more waste, and requires more processing energy than higher grade materials. Low-cost transportation of the materials is required for adequate distribution of industrial rocks and minerals. For many high-volume, low-cost materials such as crushed rock, sand and gravel, 20 miles is about the economic limit for transportation. The potential profit from development of a mineral resource must be enough to attract capital investments. Long-term loans may be difficult to obtain and are unattractive when interest rates may be high. The price must be adequate to sustain sales fluctuations. Price, quality and consumer acceptance of materials produced must be sufficient to cope with competition, either from other sources or from mineral substitutes.

Mineral Depletion

Mineral producers constantly deal with depletion of resources at sites of operations. In order to continue to operate, new material sources must be found as older deposits are exhausted. Recycling of materials, use of quarry wastes and extraction of lower-grade resources may be important alternatives to waning supplies. In 1980 the United States, with five percent of world population, consumed about 13 percent of the world's mineral resources. New technologies may create demands for materials formerly of limited usage.

Figure 3. Interpreting data from aerial photographs for possible locations of mineral deposits.

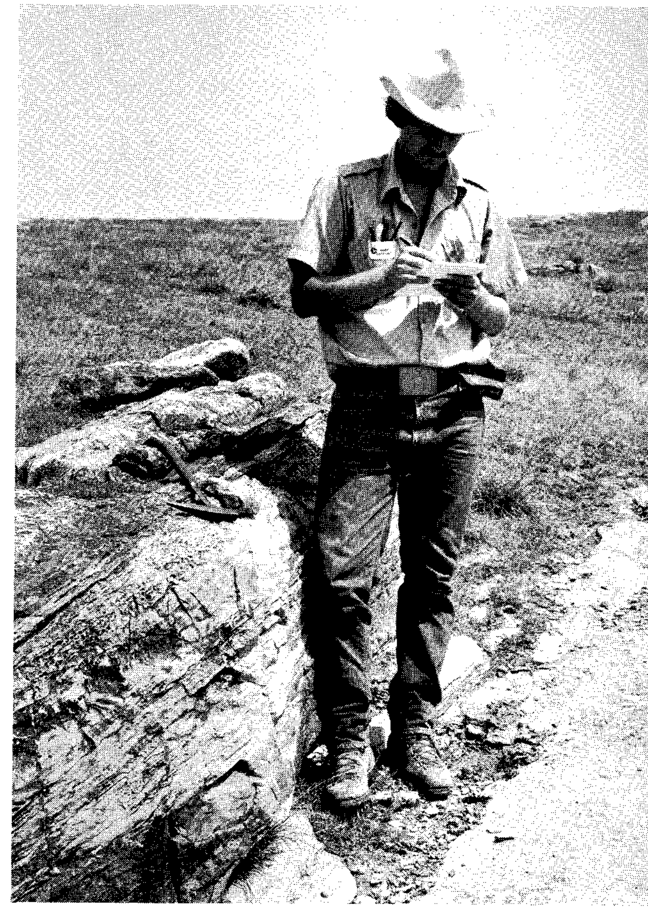


Figure 4. Geologist recording information on rock type and deformation.

RESOURCE DEVELOPMENT SEQUENCE

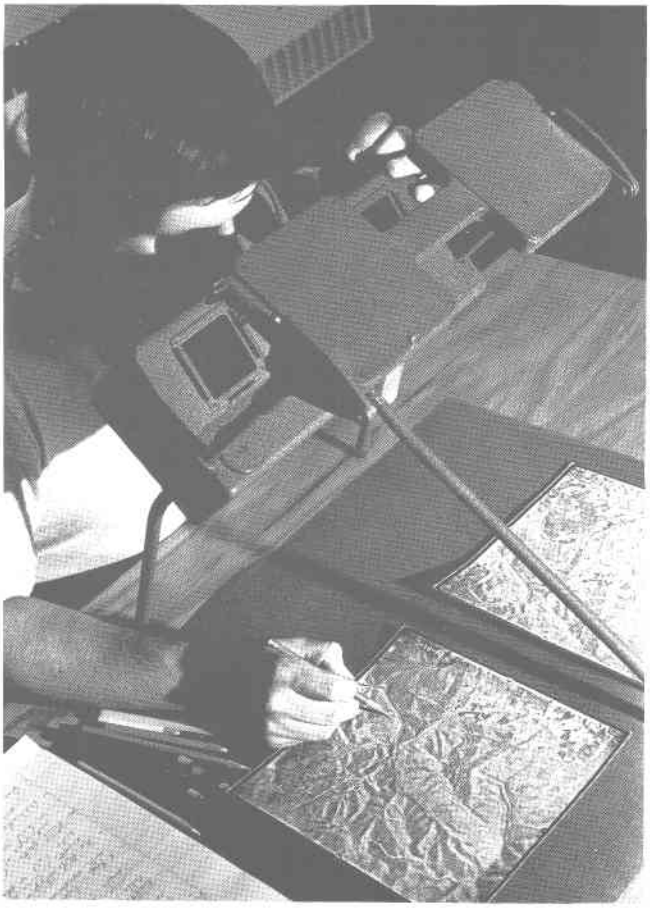
The orderly development of mineral resources, additional and future, proceeds in several distinct phases: exploration, development, extraction, processing, and reclamation.

Exploration

Exploring for rock and mineral resources involves investing in the trained personnel, equipment, and facilities needed to search for prospective areas. The best sites would be close to areas where the minerals are needed and where there would be minimal amounts of weathered rock and soil on top of the mineral resource to be developed. Unfortunately mineral deposits do not always occur where they are needed. They are not present everywhere; rather they are distributed in unique natural locations. Quarry development can take many years from the time searching for minerals begins to the time when they are available to the consumer. About one-third of this time can be devoted to addressing environmental and regulatory concerns. Sand and gravel resources can be developed more rapidly than raw materials derived from rock quarries.

Initial exploration may require three or more years. The first step in exploration is a review of existing geologic maps, aerial photographs (Figure 3), topographic maps, and geologic reports (Appendixes I and II). From this review, information is obtained as to where minerals have been found and where natural conditions are most suitable for the location of the various minerals sought. Once a general location is established, exploration for specific sites can then be made by making geophysical surveys and geologic maps. This information helps to reduce the amount of time and money spent examining various localities in the field.

Lands with the greatest potential for mineral value are purchased, leased, or options to buy are obtained. Leasing usually requires negotiating royalty payments with the owner of the mineral rights. Specific areas are evaluated by on-site geologic studies of the characteristics of rocks and their deformation (Figure 4). Where soil and vegetation mask the underlying rocks, geophysical and geo-



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More detailed investigations involve drilling test holes. Data from these holes are used to determine the amount, uniformity, and concentration of the resource. Also, an estimate can be made of nonprofitable materials to be removed before the resource can be extracted. Chemical and physical test data commonly are obtained from laboratory examination of test hole material. The amount of land disturbed by the drilling of these holes is small.

Sometimes, in order to determine the quality of the material to be extracted, bulk samples are collected and analyzed to obtain a better idea of the average content of the rock. Processing methods can be designed to handle unwanted materials which are found by these analyses. Also, these analyses can be used to identify other useful minerals that could also be marketed as by-products.

After information about the extent and concentration of the resource is obtained, an economic evaluation is made. This information is compared with the estimated costs of development, production and marketing. These data are compared with the anticipated future value of the mineral deposit in order to determine if the resource can be profitably extracted. The evaluation involves market studies, projections of anticipated prices and needs, and determination of financing costs for the duration of the project. Other considerations are operational expenditures, costs of environmental safeguards, future taxation, and the possibility of higher grade or alternate materials being developed which would reduce sales of the resource. Good long-term planning is needed before committing large sums of money for mineral production, as there are many uncertainties in such ventures.

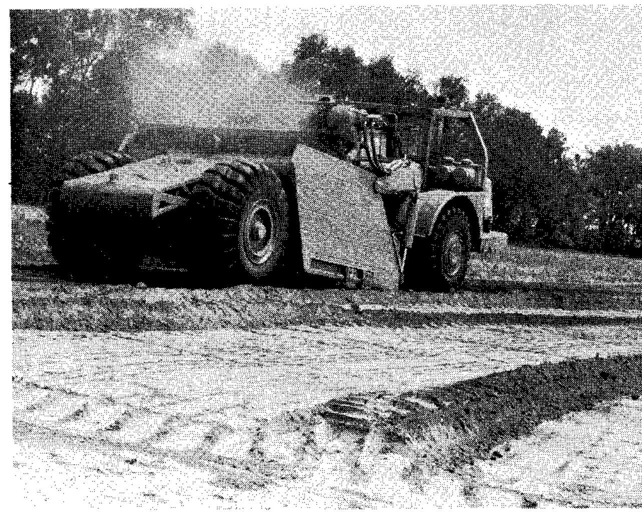

Figure 5. Removal of soil and overburden by self-loading pan prior to extraction of sand and gravel.

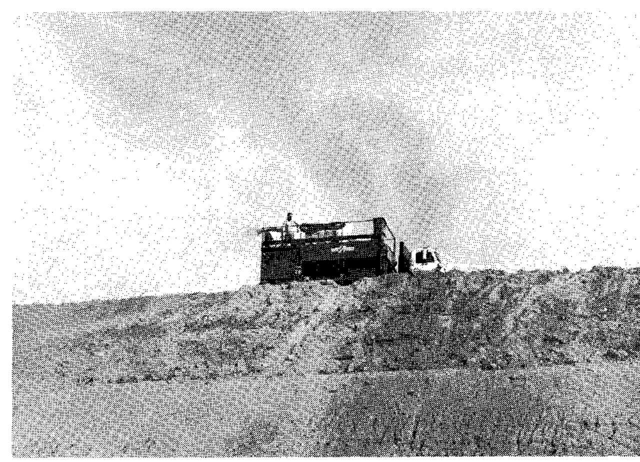

Figure 6. Hydroseeding newly constructed privacy berm with grass seed and fertilizer to retard erosion (photo courtesy of Vulcan Materials Company).

Development

Site development is carefully controlled by state and local agencies (see section on "Permitting Process" in this report). Development must conform to an operations plan approved by the Division of Mined Land Reclamation, Minerals Other Than Coal section (DMLR/MOTC) which includes the following:

1. Description of the proposed method of operation
2. Maps showing total area to be permitted and the area to be disturbed in the ensuing year
3. A drainage plan with a map
4. A statement of the planned land use to which the disturbed land is to be returned, which is amendable
5. Provisions for simultaneous reclamation with the mining operation
6. Notification to utilities of any disturbance to or within 500 feet of easements

A detailed map of the operation showing all anticipated changes to topography and vegetation, location of roads, the mining site, processing equipment, stockpiles, and buildings is usually required for local permits as well.

Preparation of the site begins with general grading to accommodate roads, buildings, processing plants, and stockpiles. The area is usually fenced before production begins.

Topsoil and overburden are removed first (Figure 5). This material can be used as berms that serve as buffers and screens to the operation or for future reclamation of the site (Figure 6).

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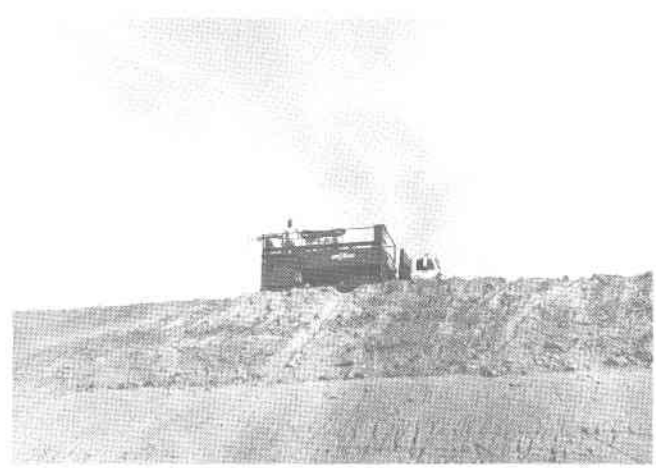

Figure 6. Hydroseeding newly constructed privacy berm with grass seed and fertilizer to retard erosion (photo courtesy of Vulcan Materials Company).

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Drainage is carefully controlled. Surface water is diverted around the site. Rainwater and ground water can be pumped into streams after suspended sediments are collected in settling ponds or can be used for dust control. Regulations generally limit the amount of rock that can be exposed by stripping to the amount used in one year, thus controlling the area subject to erosion.

Extraction

The rock must first be reduced to manageable sizes in order to extract it from the quarry. This involves blasting. Individual blasts are referred to as "shots." Many of the larger aggregate companies have trained employees who do all blasting. Most companies also retain a blasting consultant to assist them as necessary at each shot. Many smaller companies rely entirely upon the expertise of these consultants. At quarries, designing a shot begins with deciding how much rock is needed. A pattern of holes is then drilled to specified depth on top of the area to be extracted. Very often the holes are drilled far in advance (Figure 7) and are covered to prevent dirt and water from filling them.

On the day the shot is to be fired, the holes are loaded with explosive. The predominant explosive used is nitrogen-based fertilizer. Dynamite is rarely if ever, used. A water-resistant-gel explosive, is used if water is present in the holes. Loaded holes are stemmed ie. topped with crushed rock. Stemming improves the efficiency of the blast and helps to control flyrock (uncontrolled rock pieces generated by blast effect). Milli-second delay systems are a modern technique that allows each charge to fire separately. This improves the break-up effect and also helps to reduce noise, vibration, and the possibility of flyrock because the entire charge does not fire at once. Compressed air can be used to reduce the amount of explosive used in each shot. This is done to reduce costs and prevent noise and vibration problems off site. A carefully designed shot, making use of modern techniques produces safe and efficient results (Figure 8). Clear days are best for blasting as clouds can amplify blasting noise. Many operators monitor shots with seismic equipment to obtain a record of the time and intensity of the shots. These records are used by the operator in keeping shots within prescribed limits and for evidence in potential damage suits.

Sand and gravel operations are regulated by the DMLR/MOTC and use this agency's plan procedures. However, extraction techniques are vastly different than those of rock quarries in that sand and gravel can generally be extracted without blasting. Power shovels, front-end loaders, and draglines are the principal means of removing these materials (Figure 9). In Virginia, sand and gravel sites are primarily associated with river channels and old beaches. Extraction takes place either in or along existing rivers and streams or occurs in deposits of former river channels. Proximity to a river may provide water either for inexpensive plant processing or for transportation of the materials to the market.

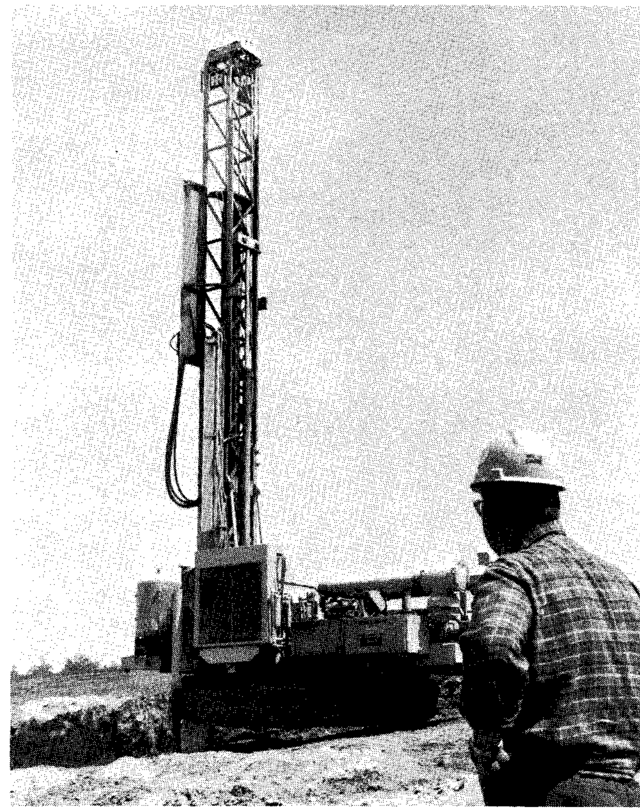

Figure 7. Drilling of shot hole for blasting.

Figure 8. Blasting granite.

Drainage is carefully controlled. Surface water is diverted around the site. Rainwater and ground water can be pumped into streams after suspended sediments are collected in settling ponds or can be used for dust control. Regulations generally limit the amount of rock that can be exposed by stripping to the amount used in one year, thus controlling the area subject to erosion.

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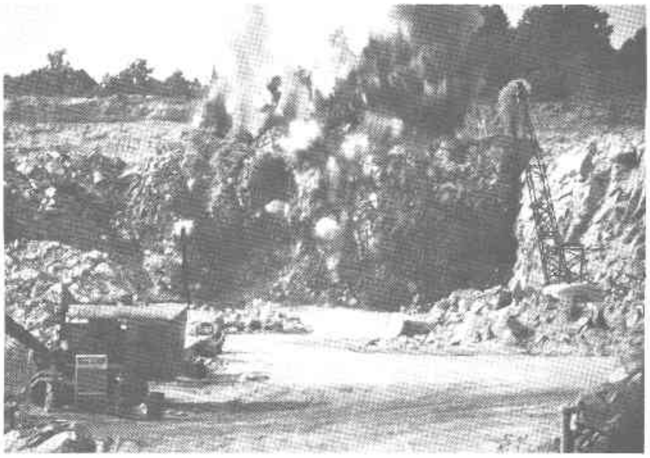

Figure 8. Blasting granite.

Figure 9. Loading gravel from drag-line cable-crane into bottom-dump haul wagon for transporting to processing plant (photo courtesy of Lone Star Cement, Inc).

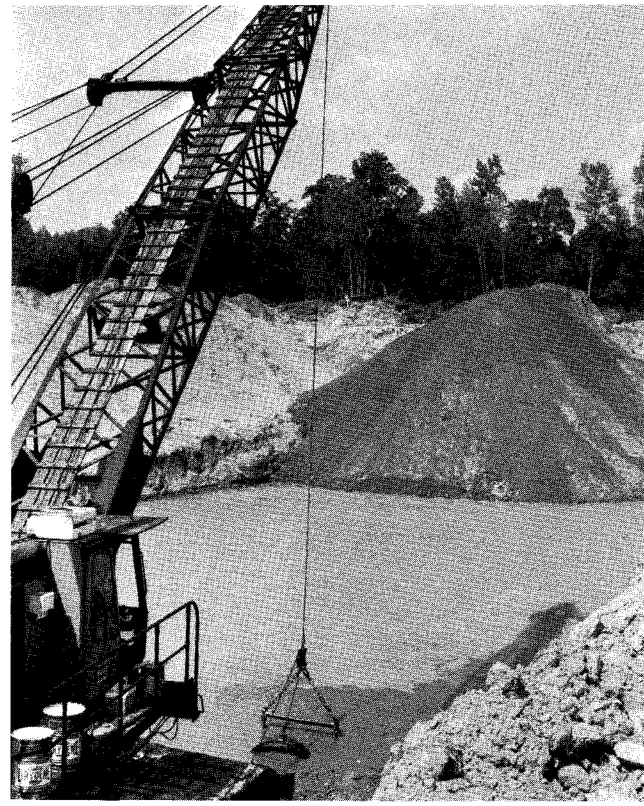

Figure 10. Drag-line crane extracting gravel and sand in foreground with overburden from adjacent pit being used as reclamation fill in background.

Sand and gravel pits may be reclaimed simultaneously with extraction (Figure 10). As mining is completed, areas are regraded, smoothed, and replanted. After operations are terminated, it is often difficult to determine that the area was ever disturbed, except for low areas which are preserved as ponds or small lakes.

Processing

After the sand and gravel is extracted, it is screened to remove oversize particles and debris and sorted into various sizes for anticipated uses. Further it is washed to remove clay, silt and other impurities (Figure 11). Gravel is often crushed for use in concrete.

Once quarry rock is blasted, it is loaded into trucks by mechanical shovel or front-end loader for transportation to the primary crusher (Figures 12 and 13). The primary crusher begins the processing phase of the operation in which the rock may be reduced in size for further crushing (Figure 14). After crushing, the rock is screened and moved by conveyor to a stockpile (Figure 14). The stockpiled material is sold for many uses in the construction industry.

Cement is prepared from crushed limestone and shale by heating these materials to certain designated temperatures. The cooled materials are then crushed and mixed with gypsum and other additives that influence the rate of cement hardening.

Lightweight aggregates are made from crushed shale or slate. These materials also go through a heating process which causes them to expand. They are then crushed to specific sizes and are used in the manufacture of lightweight concrete blocks.

Bricks in Virginia are made from schist, shale, and clay extracted from pits. This material is crushed, mixed with water, and cut into desired brick shapes and sizes. Various materials may be added to the exterior of the bricks for color or ornamental purposes. After drying under controlled conditions of temperature and humidity, the bricks are fired in kilns with temperatures of about 2000° F (Figure 15).

Feldspar marketed as "Virginia aplite" for use in making glassware is quarried in a similar

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Figure 11. Floating processing plant for sand and gravel washing and sizing; note loaded barge ready for customer delivery.

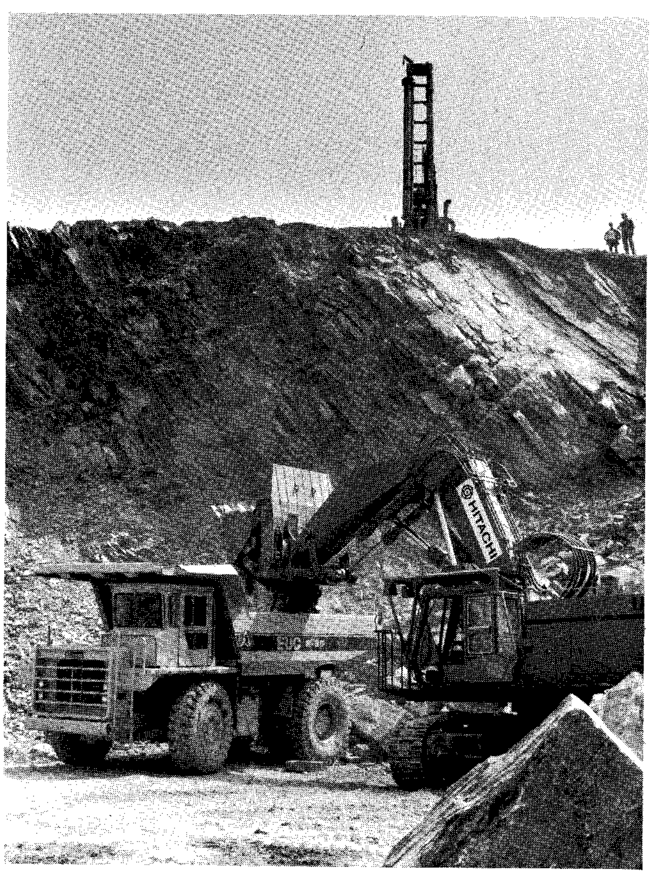

Figure 12. Loading of shot rock into a 35-ton truck by means of hydraulic shovel for transporting to crusher; on upper bench, holes for next blasting shot are being drilled.

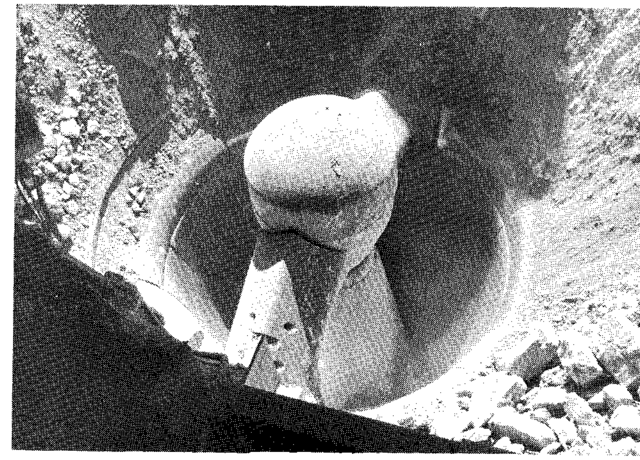

Figure 13. Primary rock crusher where rocks are crushed to a maximum size of 8 inches (photo courtesy of Vulcan Materials Company).

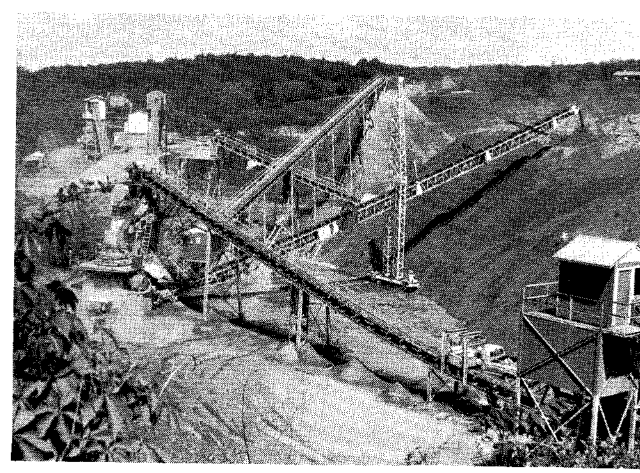

Figure 14. From primary crusher in lower right-hand part of photograph, stone is transported by belt conveyors for additional crushing, sizing, and storage.

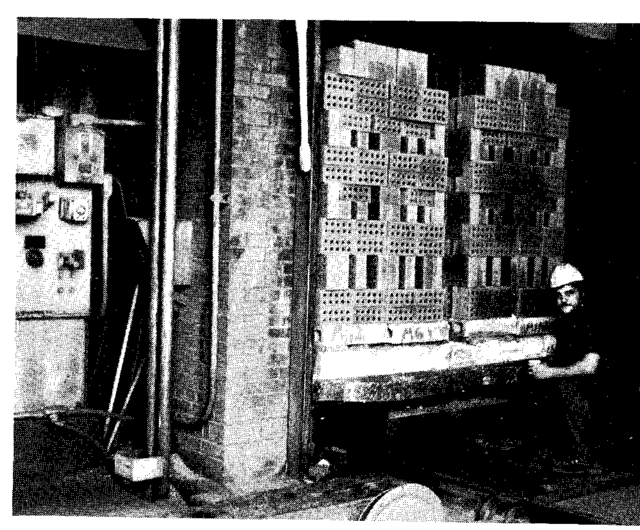

Figure 15. Firing of bricks in tunnel kiln.

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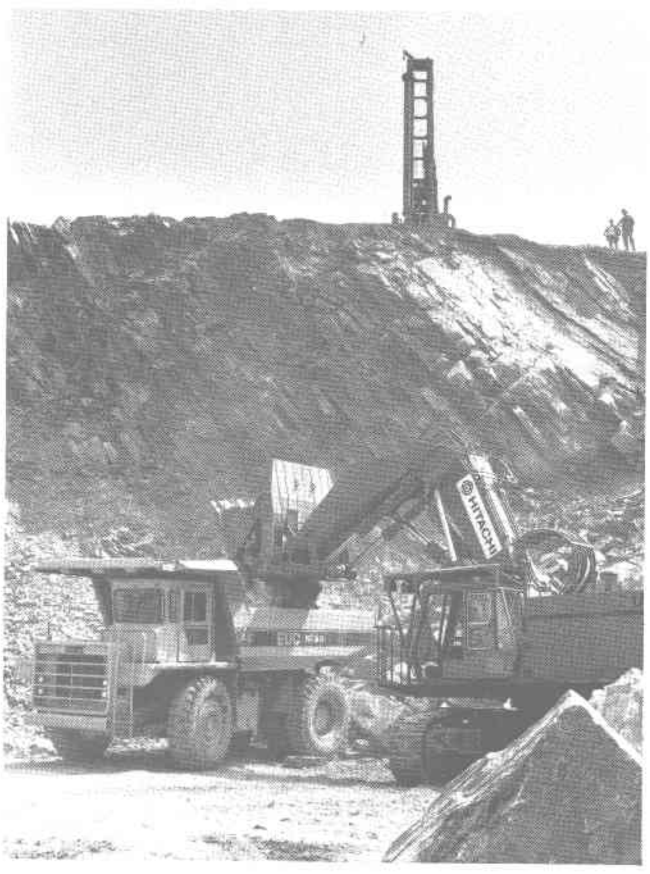

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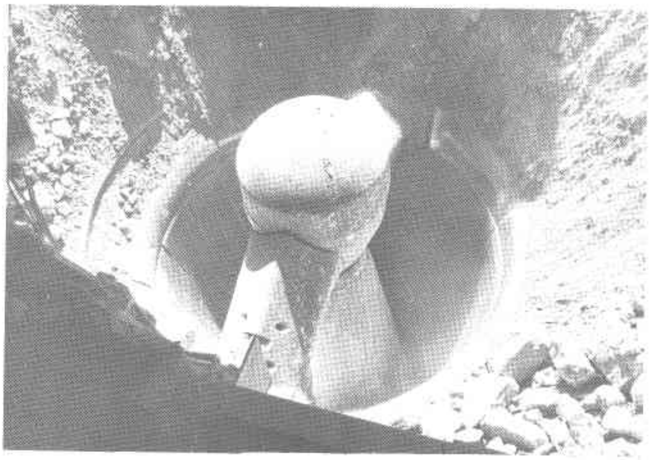

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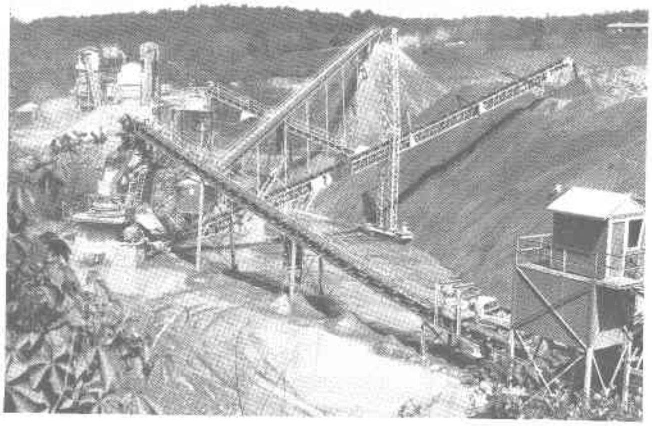

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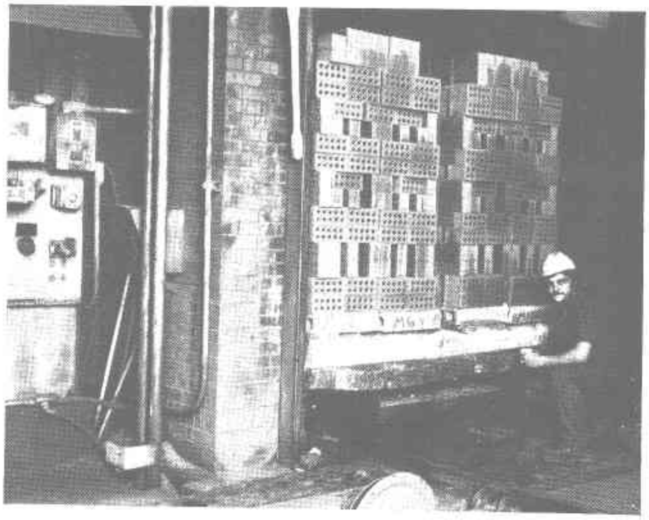

Figure 15. Firing of bricks in tunnel kiln.

manner to crushed stone. It is processed by means of crushing and gravity separation through screw classifiers and Humphrey Spirals to produce particles that are from 30 to 150 mesh in size. Unwanted minerals such as biotite, hornblende, ilmenite, and magnetite are removed by electromagnetic and hydrosizer density segregation (Figure 16). The final product is kiln dried.

Virginia produces popular stone roofing and walkway paving materials such as soapstone and slate. The large blocks of stone are checked for absence of joints and for consistency of color. They are sawed with machines into standard-size slabs. Soapstone slabs were polished and milled for use in the assembly of stoves or sinks. Slate for roofing is split (Figure 17), trimmed, and milled into shingles. Slate is also used as ornamental building facing and flooring.

Virginia is one of the world's leading producers of kyanite. This material is valued as a refractory in processes which generate extreme heat. The processing of kyanite ore begins with crushing. Clay is washed from the crushed ore and the kyanite separated and concentrated by flotation. Iron is removed magnetically after the concentrated ore is heated.

Vermiculite for use in preparing fertilizers and wallboard is extracted from a pit. It is crushed, separated from unneeded rock material, sized, and dried. Virginia is one of three states producing vermiculite.

Product Delivery

The potential success of a mineral operation generally depends upon the proximity of an existing road or railroad. In some cases, the deposit is considered of sufficient value to have a transportation system extended to it.

Quarry or pit products commonly are purchased at the extraction sites. Some companies have exhibits at the site to show how their products can be used (Figure 18).

Usually when products are ordered they must be delivered by either truck, railcar, or river barge (Figures 19, 20, and 21). Average costs of transporting stone per ton-mile are: by truck, 5-7¢ ; by rail, 1-2¢ ; by barge, ¼-½¢. Crushed stone, sand, and gravel are low-unit value items. Usually they can only be economically trucked within a twenty mile service radius before a competitor's price may affect the sale. Therefore sites for these products are located as close to the user as possible. If resources are not present where needed a much longer transportation distance may be economical.

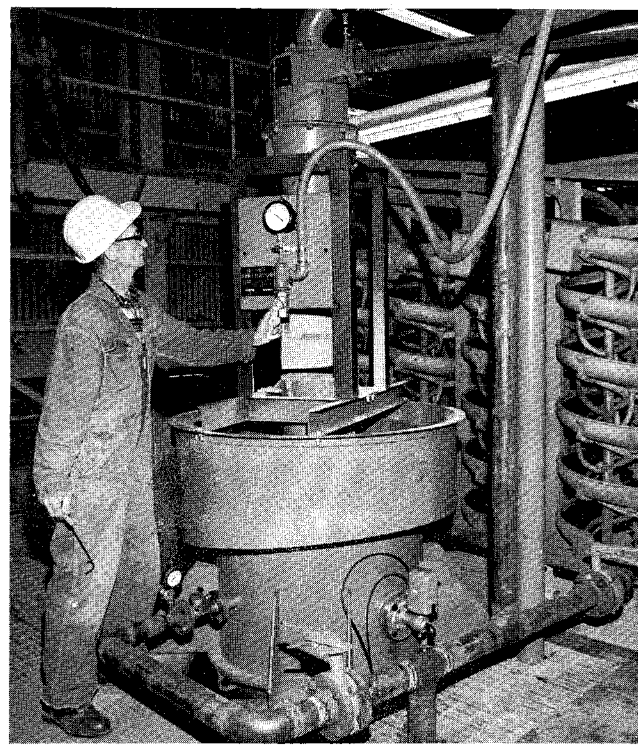

Figure 16. Hydrosizer with Humphrey Spirals behind used to separate unneeded minerals and to maintain size range in feldspar processing (photo courtesy of The Feldspar Corporation).

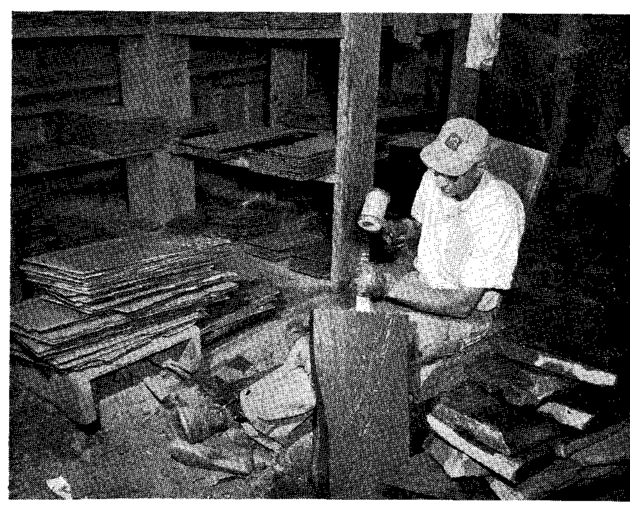

Figure 17. Hand-splitting slate shingles (photo courtesy of Arvonia-Buckingham Slate Company).

Sand from Richmond is sold in the Shenandoah Valley and crushed stone from the Piedmont area is sold in Norfolk. What other material can be purchased for $0.25 per hundred pound and last for hundreds of years as does crushed stone?

On a comparative basis, a high-unit-value item such as kyanite can be shipped farther than a low-manner to crushed stone. It is processed by means of crushing and gravity separation through screw classifiers and Humphrey Spirals to produce particles that are from 30 to 150 mesh in size. Unwanted minerals such as biotite, hornblende, ilmenite, and magnetite are removed by electromagnetic and hydrosizer density segregation (Figure 16). The final product is kiln dried.

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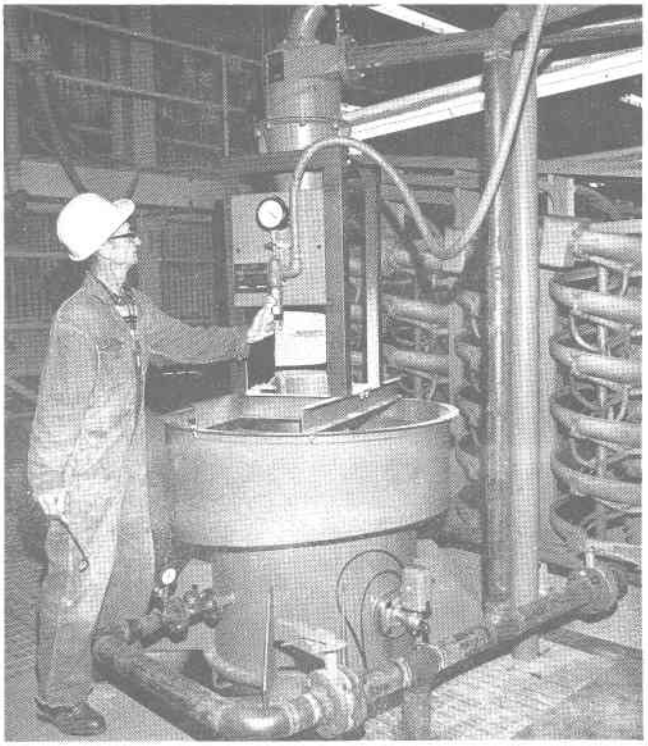

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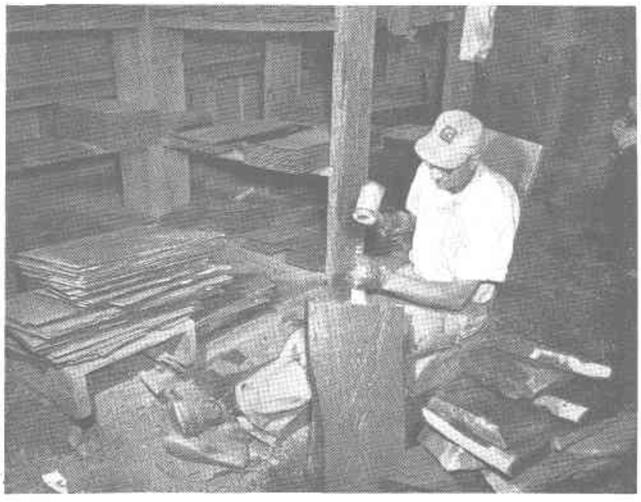

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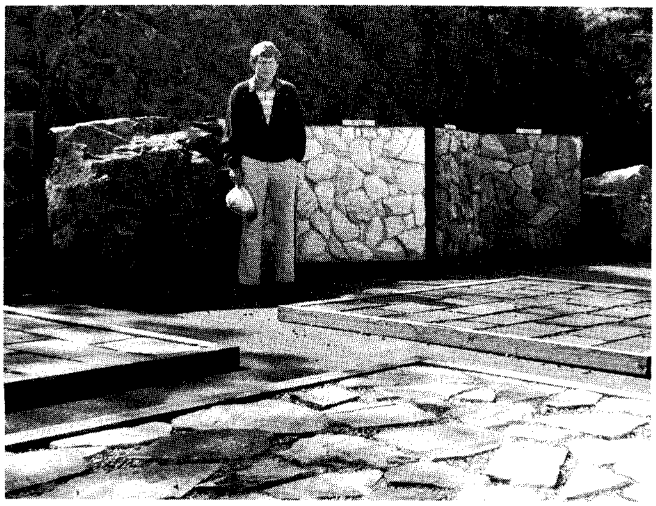


Figure 18. Stone center with various rocks for wall or patio construction.

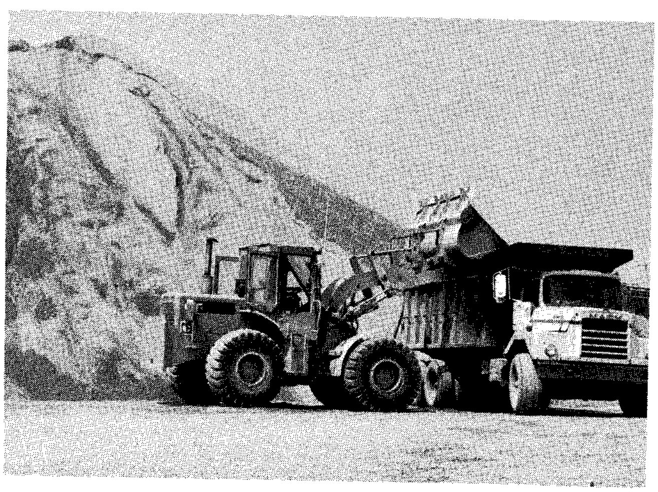


Figure 19. Crushed rock being loaded into customer's truck from stockpiles.

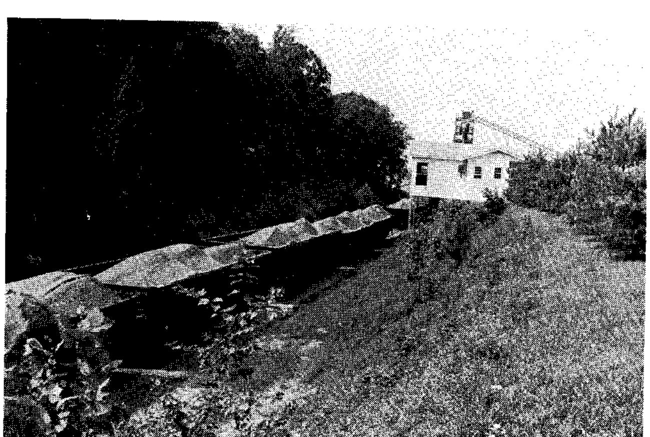


Figure 20. Loading rail cars with crushed stone for shipment to Norfolk markets (photo courtesy of Vulcan Materials Company).

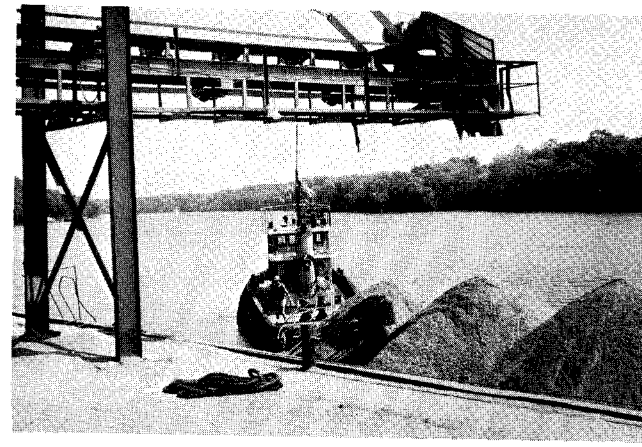


Figure 21. Barge transportation of gravel to customer.

unit-value item and still realize a profit. Transportation costs for precious metals are usually not a dominant consideration, whereas base metals require low costs to be profitable.

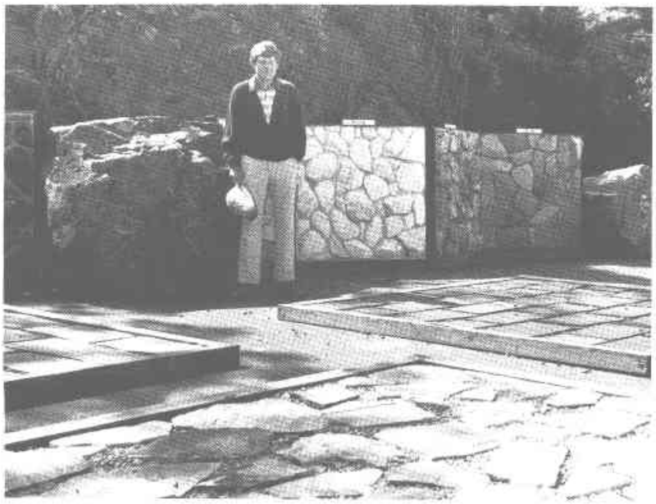
By-products

The development of additional useful by-products allows for greater use of extracted materials and lessens the cost of disposing or reclaiming of waste products. An example of a by-product is the use of finely crushed granite and limestone material as a soil conditioner. Sand produced from the processing of kyanite is used as abrasive and masonry sand, as road base and paving mixtures, and as fillings for golf course traps. Slate is crushed and incorporated into asphalt paving. Fine-sized diabase materials are used as an asphalt filler. Fines from crushed feldspar are used as road aggregate.

Reclamation

Mineral extraction is a temporary land use. While a quarry may occupy a site for several decades, eventually the mineral is exhausted or the market can no longer support extraction. Reclamation is the process of returning mined land to a safe and stable condition which can support a productive use either concurrent with extraction or at its completion.

In Virginia, reclamation of mined land (exclusive of coal mining) is overseen by the Division of Mined Land Reclamation, Minerals Other Than Coal (DMLR/MOTC). It is their responsibility to approve, permit and monitor mining activities, ensuring that sites are reclaimed properly when



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All pit and quarry operators with five years of satisfactory operation in Virginia must pay into a Minerals Reclamation Fund initially $50 per acre for land to be disturbed during the next year. Each succeeding year a payment of $12.50 per acre to be disturbed must be made to the Fund until a total of $500 per acre permitted to be disturbed has been paid. When there is a total of $400,000 in the Fund, bonds and other securities previously posted by members of the Fund for satisfactory reclamation will be released. Fund payments per acre will be returned as these acres are satisfactorily reclaimed. Interest from the Fund is used for the reclamation of orphaned lands.

Operations plans are flexible in that the Director of the Department of Mines, Minerals and Energy can specify provisions according to the unique conditions and characteristics of a particular site or operation. In general, a plan describes specifications for surface grading and restoration, but it also contains provisions for the following: protection of the public safety, treatment of toxic material, general maintenance of the site, handling of spoil and stockpiles, removal and storage of topsoil, visual screening, erosion control, and conditioning of the soil.

A major provision of the operations plan is that it includes a planned use to which the affected land is to be returned through reclamation. There are a wide variety of uses for reclaimed mine sites. Some of these are:

- reservoir for protection from possible fires at a plastic plant, Orange County
- irrigation system for a golf course, Martinsville
- office and industrial buildings, Fairfax County
- residential site, Lynchburg City
- lakefront properties, Hampton Roads area
- reclaimed pit for farming, Charles City County
- underwater demolition testing, Campbell County
- fill site for construction debris, Fredericksburg
- settling facility for mud and chemicals from Fairfax County Water Authority

Possibilities for use of previously mined land are limited only by physical constraints and imagination (Figures 22, 23, and 24). The National Crushed Stone Association sponsors an annual competition for landscape architects in adaptive reuses of quarries. Many entries over the years have come from Virginia universities.

Four jurisdictions, which enforce local reclamation ordinances, have been exempted from filing application to DMLR/MOTC. They are Fairfax County, Henrico County, Isle of Wight County, and the City of Virginia Beach. These jurisdictions have standards which are acceptable to the Division; even so, their enforcement program is reviewed annually.

ENVIRONMENTAL SAFEGUARDS

Quarries and pits are carefully regulated by federal, state, and local governments concerning the effects they are allowed to have on the environment. The major effects relate to blasting, plant appearance, noise, dust, truck traffic, nearby surface and groundwater pollution.

Blasting effects fall into several categories: noise, concussion, and ground vibration. In Virginia, state law limits blast noise to a 140 decibel peak at the blast site. Ground vibration is measured as ground particle velocity, the speed at which vibration travels. The state standard is set at 2.0 inches per

Figure 22. House located in inactive quarry, Lynchburg.

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Possibilities for use of previously mined land are limited only by physical constraints and imagination (Figures 22, 23, and 24). The National Crushed Stone Association sponsors an annual competition for landscape architects in adaptive reuses of quarries. Many entries over the years have come from Virginia universities.

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ENVIRONMENTAL SAFEGUARDS

Quarries and pits are carefully regulated by federal, state, and local governments concerning the effects they are allowed to have on the environment. The major effects relate to blasting, plant appearance, noise, dust, truck traffic, nearby surface and groundwater pollution.

Blasting effects fall into several categories: noise, concussion, and ground vibration. In Virginia, state law limits blast noise to a 140 decibel peak at the blast site. Ground vibration is measured as ground particle velocity, the speed at which vibration travels. The state standard is set at 2.0 inches per

Figure 22. House located in inactive quarry, Lynchburg.

Figure 23. Reclaimed gravel pit being used for wheat farming at historical Shirley Plantation.

second immediately adjacent to any building not constructed to withstand that vibration and which is not on the property or leased to the quarry operator. When the blast site is within 2000 feet of an inhabited building, the velocity limit may be lowered to 0.5 inches per second. Detailed records of each blast are required. Using modern blasting techniques, operators can usually stay well within the state requirements. Local governments, however, may enact stricter standards for blasting.

Hours during which blasting is allowed are usually locally controlled. It is common practice for quarry operators to notify their neighbors before they blast or to blast at the same time each day.

Plant appearance plays an important role in how the public feels about an operation. It may be possible to design buildings to conform with local architecture except for highly functional equipment. A well-maintained site, free of unnecessary clutter, is not only more pleasing to the eye, but is safer for the employees. Buildings and stationary equipment can be painted colors that blend into the landscape. Landscaping, utilizing local natural materials, can serve as examples of and ideas for using the products available from the operation. Where visual shielding is needed, landscaped and stablized berms are constructed and trees are planted (Figure 25).

Figure 24. Reclaimed quarry being used for underwater demolition testing in the Lynchburg area.

Noise emanates from production processes and movement of heavy equipment (power shovels, front loaders, MSHA beepers, drag lines, trucks, and crushers). The off-site effects of noise can be limited by constructing berms around the site (earth berms, walls, or rows of trees), enclosing crushers, and reducing the grades along which

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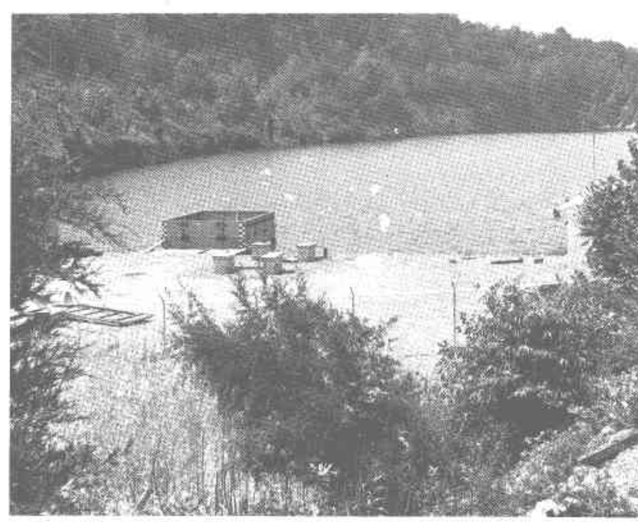

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Dust is controlled with a variety of suppression methods. Water is commonly sprayed on stockpiles, haulroads, and on materials traveling along conveyor belts. An alternative method utilizes covered conveyors. Screens and sieves are commonly enclosed in bag houses where particulates are filtered from the air (Figure 26). These houses also serve to reduce noise. Internal roads can be paved, or sprayed with water or dust suppression compounds.

Truck traffic is often hard for operators to control once the trucks have left their property. Before trucks leave the site, their load can be sprayed at a water station to stabilize fine material (Figure 27). The trucks also need to be inspected for loose material on tailgates and running boards, and the load should be covered with a tarpaulin. Hours for hauling can be controlled so as not to conflict with those used for commuting to and from work or school. The Virginia Department of Highways and Transportation can require that safe acceleration/deceleration lanes are constructed by the operators onto local roads and highways. Local officials may limit the amount of truck traffic for noise that might have an adverse effect on certain uses of the land.

Off-site water pollution and erosion are carefully regulated during the construction and operation phases. Settlement ponds (Figure 28), riprap, hay bales, weep dams and many other techniques are utilized to stabilize and trap sediments on the site. Water used for dust suppression or to wash sand and gravel is often recirculated on site, thereby reducing any off-site effects and maximizing the use of the water. Affected streams are rip-rapped to reduce erosion.

Groundwater effects are difficult to establish. Typically quarries are located in dense rock materials with low water-bearing characteristics. Because there is little groundwater present or water movement is so slow, there is usually no significant effect on the water table. Movement of groundwater is generally into the excavated area, so that ground-water pollution is not a problem.

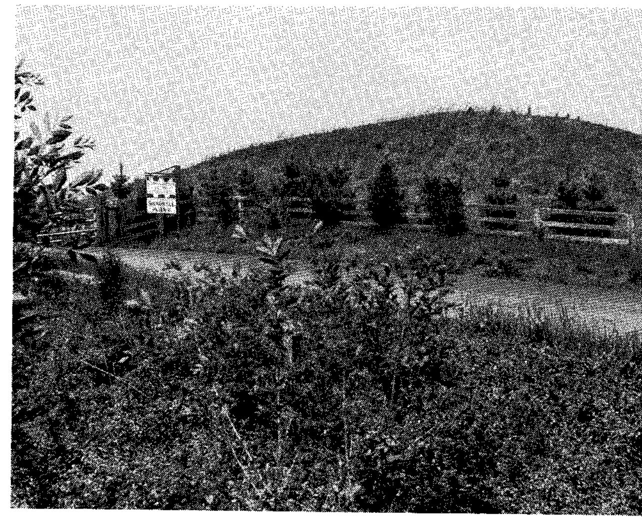

Figure 25. Berm with trees for visual and sound shielding of quarry.

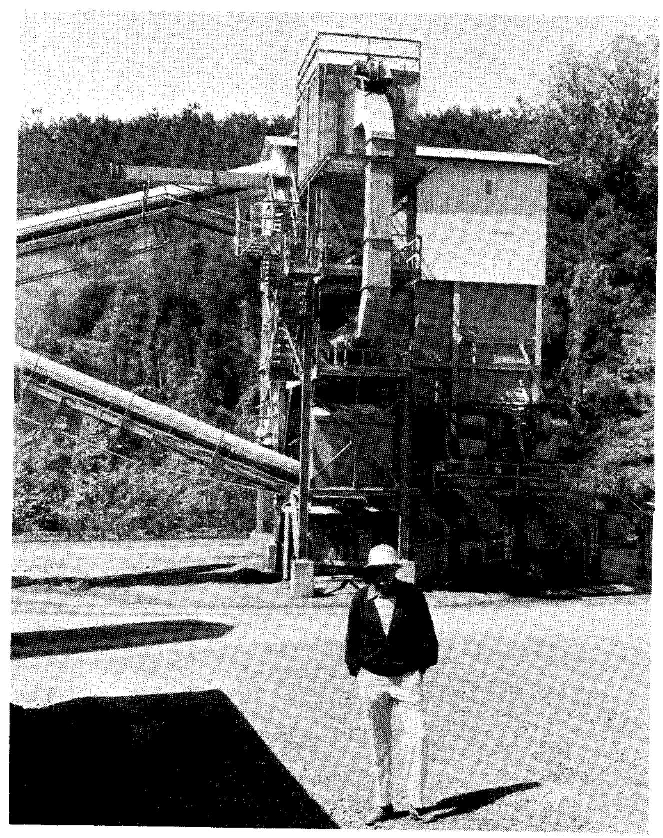

Figure 26. Bag house to control dust from crushed material.

PERMITTING PROCESS

After it has been determined that minerals can be economically extracted from a site, the developer must begin the permitting process. This can involve varying degrees of complexity, depending upon the type of material and the county in which the site is located. Exploration for mineral resources now requires permits in several counties.

The permitting process for a rock quarry in Virginia generally is as follows:

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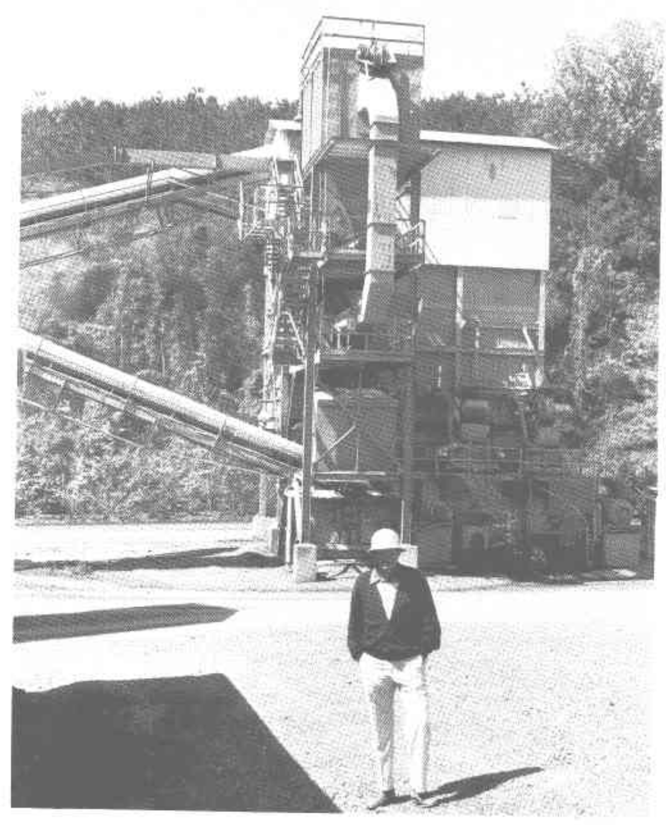

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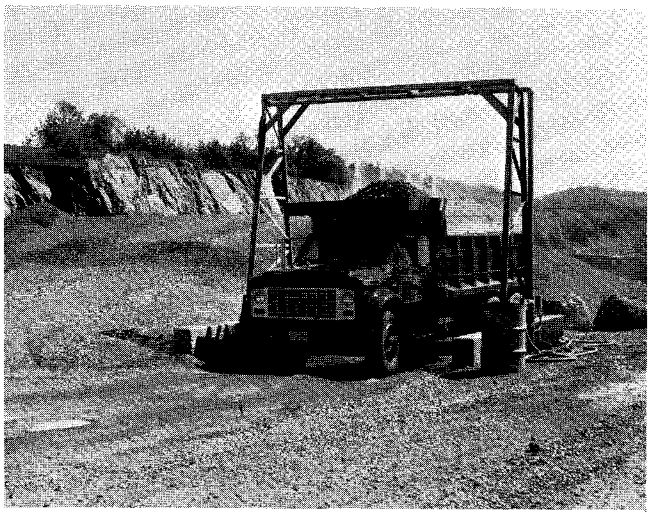

Figure 27. Water spraying of stone load to control dust.

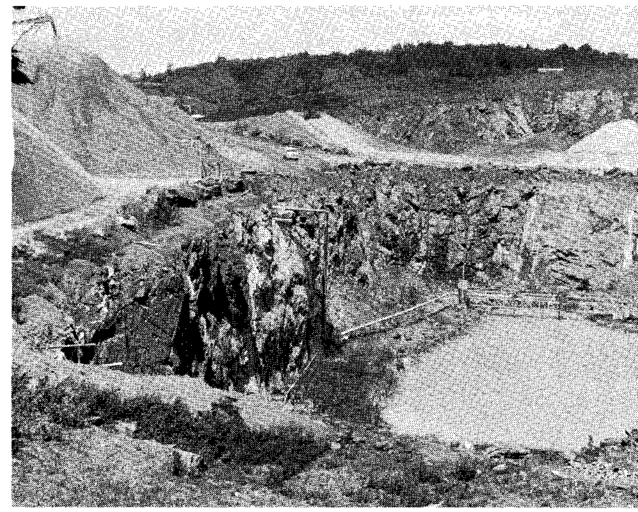

Figure 28. Settlement pond in quarry to keep adjacent streams clean and to serve as water source for dust suppression.

Local

- Pre-application conference with local planners or agents for the board of supervisors or city council
- Application filed with the planning commission, which is reviewed by the planning department and other local appointed agencies
- Recommendations forwarded by the planning commission to the board of supervisors or the city council with public hearings then held; special conditions may be negotiated and added if the permit is granted

If an application is denied during the initial stage by an appointed agency, then the developer can appeal to the board of zoning appeals or initiate court review. If an applicant is denied by an elected governing body (e.g., board of supervisors), then generally another review cannot be made for twelve months.

State

The authority of state agencies concerning extractive industries comes from legislative actions in the *Code of Virginia*. Agencies develop rules and regulations to implement the *Code*. See Appendix III for addresses of these regulatory agencies. Federal regulations about the extractive industry are often administered by the State. The following are regulatory activities of state agencies involved in permitting:

Division of Mined Lands Reclamation, Minerals Other Than Coal Section

- operations and reclamation plan required to be submitted
- public hearings are held for adjacent land owners
- any appeals of orders, rules, or regulation of DMLR/MOTC are made to the Board of Surface Mining Review
- receives bond and permit fees
- issues mining permits
- enforces extraction and reclamation regulations adopted by Department of Mines, Minerals and Energy
- license renewal subject to the submission of an annual report, and updated map of all operations, and a renewal fee
- operates Mineral Reclamation Fund

State Water Control Board

- administers state and federal regulations concerning water pollution
- NPDES (National Pollutant Discharge Elimination System) permit required when mining or other extraction/exploration activities result in discharge or potential discharge into State waters
- State No-Discharge Certificate required where there is no discharge to state water, but potential for discharge exists
- federal 401 certification sets water quality standards for the effects to the construction of impoundments or structures and dredging and filling operations in navigable waters

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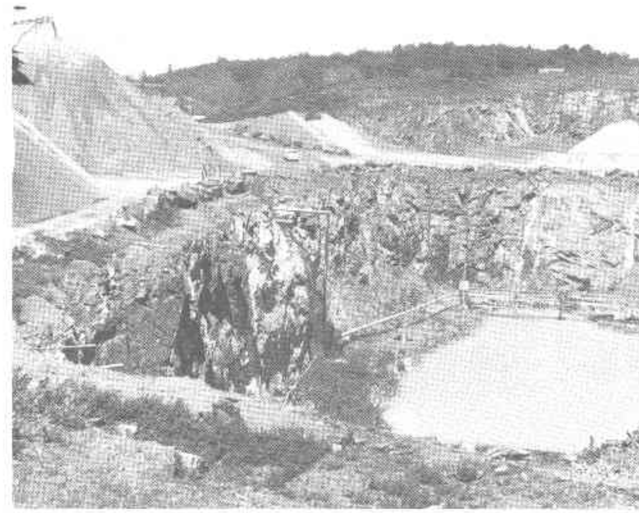

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- no fee is involved for a permit to mine

State Air Pollution Control Board

- issues permits for the construction and operation of stationary air pollutant-emitting, industrial activities
- enforces regulations established by Environmental Protection Agency for air quality
- no fee is collected

Virginia Marine Resources Commission

- requires permit for mineral extraction in state-owned waters or wetlands; for projects costing $10,000 or less - $25 fee; projects costing more than $10,000 - $100 fee
- minimum royalty of 20¢ and a maximum of 60¢ per cubic yard of material removed from state-owned beds
- can grant five-year renewable leases except for designated public oyster banks
- a joint permit application has been developed for state-owned submerged land, or wetlands, for applicable state and federal agencies

Division of Mines

- Enforces mining regulations established within the *Code of Virginia*
- issues licenses for all mining activities; $75 annual fee ($20 for sand and gravel operations less than five acres)
- reviews mining procedure and design
- responsible for on-site inspection of construction and operations as they relate to worker safety, especially fire, noise, ventilation, blasting, and equipment safeguards
- license renewal subject to the submission of an annual tonnage schedule report and an updated map for some operations

Virginia Department of Highways and Transportation

- sets specifications and standards for modifications made to existing roads and highways for entry to extraction sites
- makes on-site inspections of construction of any such modifications
- permit fee and bonding are required

Federal

Federal regulations about the extractive industry can be administered by the State as:

- 1) State powers are granted by the federal government in the Constitution of the United States. States can exercise these powers as they choose.
- 2) the federal government also mandates some state action; air and water protection must be carried out by the state-mandating legislation.
- 3) states regulate many environmental concerns; if they do not the federal government does.

Title 40 of the Code of Federal Regulations generally governs many of the controls related to environmental impact assessment, land-use planning and the standards and criteria in effect during the operation of a quarry or pit. There are many federal laws pertaining to mineral development (Figure 29).

In most cases mining activities do not require a federal permit. The Environmental Protection Agency may issue permits in certain instances, but their authority generally is delegated to state agencies. The Army Corps of Engineers issues a 404 permit for the construction of impoundments or structures and for dredging and filling operations in navigable waters, wetlands, and the ocean. For addresses of federal regulatory agencies see Appendix III.

LAND-USE CONTROLS

Land-use controls are administered by local governments. State-enabling legislation delegates powers to local governments to enact ordinances that protect the "health, safety, morals, and general welfare" of their citizens. These powers may be delegated either by charter grants or by the enactment of general "enabling statutes." State law takes precedence over local law; local ordinances cannot exceed greater power than is delegated by the State.

The power of local land-use controls is derived from the ability of a local government to prepare comprehensive plans, zone, and pass special ordinances. Counties and municipalities are required to prepare a comprehensive plan to ensure the orderly growth within their jurisdiction; these often have a section on mineral resources (Appendix IV).

Although a comprehensive plan expresses public policy, it cannot be used to enforce that policy. Its primary function is to guide future policy and development. A well-prepared plan alerts local officials to possible land-use conflicts and other pressures brought on by growth. To keep up with changing conditions within a locality, comprehensive plans shall, by law, be reviewed at least once every five years.

Zoning ordinances can serve as the legal means by which a local government implements the comprehensive plan. Zoning divides the community into

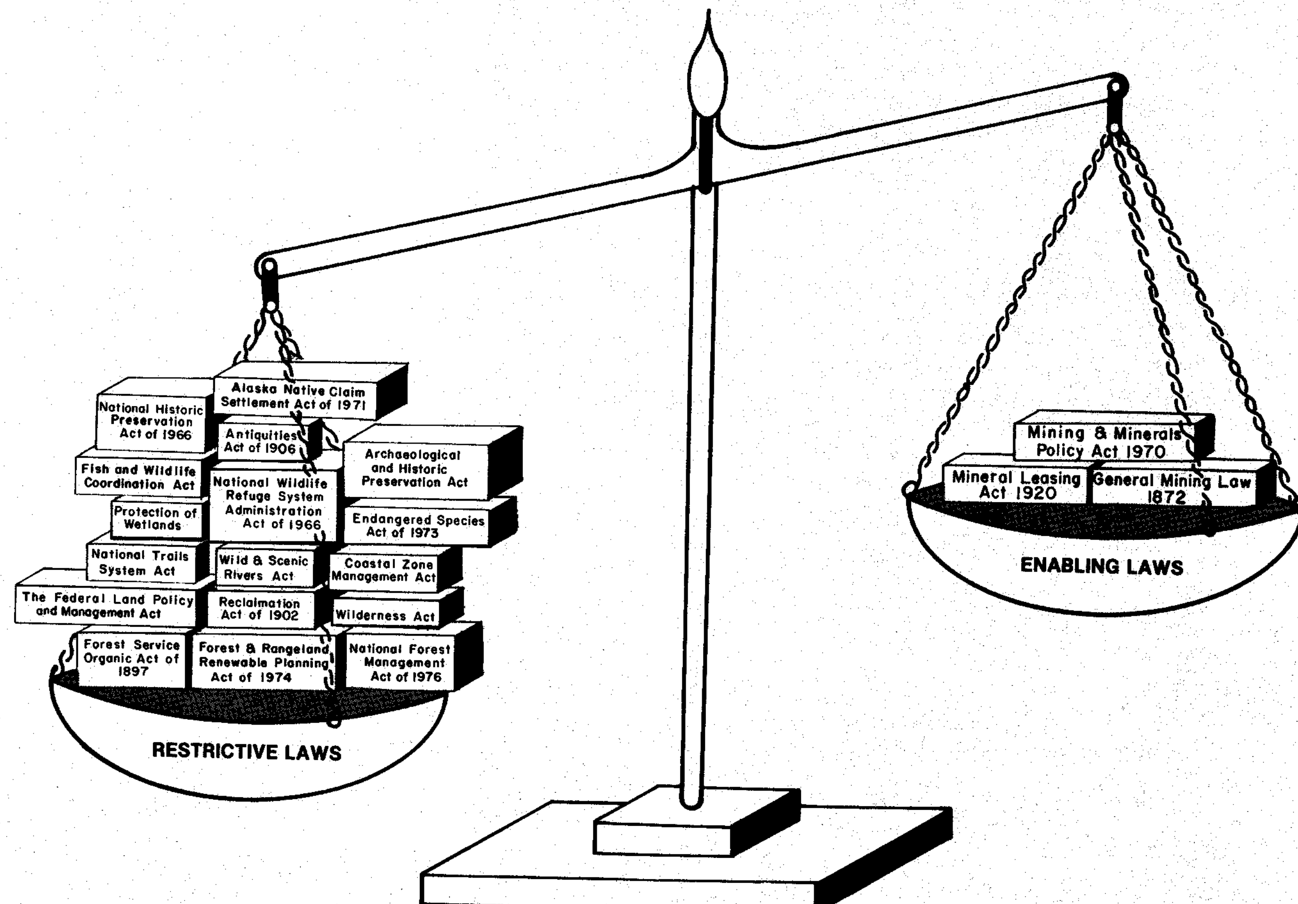

Figure 29. Federal laws related to mining.

districts which have the same and compatible uses in order to "regulate, restrict, permit, prohibit, and determine" land use, buildings and the land they occupy, as well as mining and other forms of excavation. Mining activities are specifically mentioned in zoning ordinances. Because the site of these activities is determined by existing conditions which cannot be relocated, they must be considered to avert land-use conflicts.

Zoning districts are generally divided among the following categories: agricultural, commercial, industrial, residential, conservation, recreation, and floodplain. Mining and extractive industries are included in a specific use category as mineral resource-extraction districts. Such industries may be incorporated into agricultural and industrial zoning districts upon application for a zoning permit.

In the case of mining, an overlay zoning district can be used to apply performance standards for extraction and processing that are not addressed in the original zone. These overlay districts can also be placed over compatible sites of future extraction for the purpose of alerting developers to the possible use of the area for mineral extraction.

Zoning ordinances are the legal standards that must be complied within each district. Appeals for cases involving zoning disputes are made to the board of zoning appeals.

Specific uses for a particular zone are listed within the zoning text. In addition, the text may list uses which are allowed only after the administering body grants a special or conditional use permit. These special uses are usually those having an impact on adjacent areas and the community as a whole (airports are often in such a classification) but are in harmony with the intent of the district. These permits allow the administering body to take a close look at a project to make sure it will be a compatible use and to place the special restrictions or conditions of operation on the project that it deems necessary.

Another option determining land use under a zoning ordinance is that of a conditional zoning. Conditional zoning is a process through which a zoning reclassification takes place. This rezoning takes place subject to certain conditions proffered or volunteered by the applicant which would apply in addition to those set forth in the zoning text.

Approximately 57 counties of Virginia's 95 counties have zoning ordinances. See Appendix V for information relating to mineral extraction in Virginia county zoning ordinances. The other counties rely entirely on standards established in the state mining and reclamation regulations to control local mining operations, or on special provisions written into the subdivision ordinance. Subdivision ordinances are required by the *Code of Virginia* (Title 15, Chapter 11, Secs. 15.1-465 through 15.-485), and they are generally used in association with residential development; however, they can be used to establish standards for any type of land development.

Local governments are also empowered by the State to enact special ordinances. These ordinances can specifically address mining, but more often mining is cited in a generalized ordinance. Noise ordinances are perhaps the most common exercise of these powers.

FUTURE USES OF VIRGINIA'S RESOURCES

In the future, American technology and industry will not only require resources for uses presently being satisfied by some minerals, but will also require minerals for uses which have not yet been developed. Increasing research will be applied to techniques for recycling materials, using waste items formerly discarded during processing, and utilizing minerals of lower grade.

Information on future uses of Virginia resources is available from the Economic Section, Virginia Division of Mineral Resources. Uses of kyanite may be developed in the making of aluminum-silicon alloys; floor and wall tile; spinnable mullite fibers; and blown-wool refractory insulations. Magnetite separated from kyanite can be processed and mixed into Portland cement. Beryl has potential uses in the manufacture of metal alloys for development of space vehicles.

By-products from feldspar processing, apatite, rutile, ilmenite, and sphene are stockpiled for future uses. Feldspar fines have potential as flux material for brick manufacturing.

Greensand can be used as an ion-exchange medium for disposing of toxic materials at waste disposal sites. Slate has the potential use as raw material for the production of mineral wool and as material on which to place seed oysters.

Fines from crushing of some igneous and metamorphic rocks, as well as with feldspar fines and greensand minerals are possible sources for low-grade supplies of potassium. Tailings from some former metal mines could be used as an agricultural limestone. Soapstone scrap can be utilized as flagstone. Materials from aggregate quarries can be used if they have the proper characteristics for concrete, mine dust, mortar sand, and slurry seal.

APPENDIXES

APPENDIX I: GENERAL REFERENCES ON MINERALS AND MINERAL RESOURCES

Most of these references are available for sale from the Division of Mineral Resources except those with "*". A List of Publications is available from the Division.

The Mineral Resources of Virginia, by T L. Watson, J. B. Bell Co., Lynchburg, Va., 618 p., 1907.*

Proceedings of Symposium on Mineral Resources of the Southeastern United States, edited by F. G. Snyder, The Univ. of Tennessee Press, 236 p., 1950.*

Base- and Precious-metal and Related Ore Deposits of Virginia, by G. W. Luttrell, Virginia Division of Mineral Resources Mineral Resources Rept. 7, 167 p., 1966.

Mining and Mineral Operations in the United States, by Bureau of Mines Staff, Washington, D. C., 90 p., 1967.*

Reclamation of Depleted Sand and Gravel Sites in Eastern Virginia, by R. F. Pharr, Virginia of Division of Mineral Resources, Virginia Minerals, vol. 13, no. 3, 1967.

Mineral Resources of The Appalachian Region by U. S. Geological Survey and Bureau of Mines Staff, U. S. Geol. Survey Prof. Paper 580, Washington, D. C. 492 p., 1968.*

Ore Deposits of the Southern Appalachians, by R. A. Lawrence: *in* Ore Deposits of the United States 1933-1967, vol. 1, A.I.M.E., p. 159, 1968.*

Minerals of Virginia, by R. V. Dietrich, Research Division Bulletin 47, Virginia Polytechnic Institute, 325 p., 29 pls., 2 figs., 1970.

United States Mineral Resources, by D. A. Brobst and W. P. Pratt, editors, U. S. Geol. Survey Prof. Paper 820, 722 p., 1973.*

Industrial Minerals and Rocks, by S. J. Lefond, Editor, American Institute of Mining, Metallurgical and Petroleum Engineers, New York, 1360 p., 1975.*

Production of Mineral Resources in Virginia, by D. C. Le Van, *in* Contributions to Virginia Geology - III, Virginia Division of Mineral Resources, Pub. 27, p. 7-21, 1978.

Mineral Facts and Problems, by Staff, U. S. Bureau of Mines, Bull. 671, 1060 p., 1980.

Rocks and Minerals of Virginia, by M. P. Phillips, Virginia Division of Mineral Resources, 20 examples, 6 p., text, 1980.

Minerals Yearbook, by Staff, U. S. Bureau of Mines, vol. 1, Metals and Minerals, 968 p., 1981.*

The Mineral Industry of Virginia, by D. H. White and P. C. Sweet, U. S. Bureau of Mines, Washington, D. C. preprint, 1983.

Virginia's Mineral Industry by P. C. Sweet, Virginia Division of Mineral Resources, Virginia Minerals vol. 29, no. 3, 9 p., 1983.

Directory of the Mineral Industry in Virginia, by P. C. Sweet, Virginia Division of Mineral Resources, 28 p., 1983.

Mineral Industries and Resources of Virginia, by P. C. Sweet, Virginia Division of Mineral Resources, one map, 1983.

APPENDIX II: REFERENCES FOR RESOURCE COMMODITIES

Selected references for information on specific Virginia resources are listed below in chronological order of their publication. Most of these references are available for sale from the Division of Mineral Resources except those with "*". A List of Publications is available from the Division.

ARSENOPYRITE

Base- and Precious-metal and Related Ore Deposits of Virginia, by G. W. Luttrell, Virginia Division of Mineral Resources: Mineral Resources Rept. 7, 167 p., 1 pl., 1 table, 1966.

BARITE

Barite Deposits of Virginia, by R. S. Edmundson, Virginia Geological Survey Bull. 7, 85 p., 15 pls., 15 figs., 2 tables, 1938.*

Base- and Precious-metal and Related Ore Deposits of Virginia, by G. W. Luttrell, Virginia Division of Mineral Resources: Mineral Resources Rept. 7, 167 p., 1 pl., 1 table, 1966.

BAUXITE

Bauxite Deposits of Virginia, by W. W. Warren, J. Bridge, and E. F. Overstreet, U. S. Geol. Survey Bull. 1199-K, 17 p., 1965.*

Geology of the Staunton, Churchville, Greenville, and Stuarts Draft Quadrangles, Virginia, by E. K. Rader, Virginia Division of Mineral Resources Rept. Inv. 12, 43 p., 4 maps in color, 14 figs., 4 tables, 1967.

BRICKS

Structural Clay Products Industry, by Robert S. Wood, Virginia Division of Mineral Resources, Virginia Minerals, vol. 8, no. 2, 1962.

CLAY MATERIALS

Clay Deposits of the Virginia Coastal Plain, by Heinrich Ries with a chapter on The Geology of the Virginia Coastal Plain, by W. B. Clark and B. L. Miller, Virginia Geol. Survey Bull. 2, 184 p., 15 pls., 10 figs., 1906.*

CLAY

Clays of the Piedmont Province, Virginia, by Heinrich Ries and R. E. Somers, Virginia Geol. Survey Bull. 13, 86 p., 15 pls., 1917.*

Clays and Shales of Virginia West of the Blue Ridge by Heinrich Ries and R. E. Somers, Virginia Geol. Survey Bull. 20, 118 p., 14 pls., 8 figs., 1920.*

Analyses of Clay, Shale and Related Materials-Northern Counties, by J. L. Calver, H. P. Hamlin, and R. S. Wood, Virginia Division of Mineral Resources: Mineral Resources Rept. 2, 194 p., 1961.

Structural Clay Products, by R. S. Wood, Virginia Division of Mineral Resources, Virginia Minerals, vol. 8, no. 2, 1962.

Analyses of Clay, Shale and Related Materials-West-Central Counties, by J. L. Calver, C. E. Smith and D. C. Le Van, Virginia Division of Mineral Resources: Mineral Resources Rept. 5, 230 p., 3 figs., 1964.

Analyses of Clay, Shale and Related Materials-Southwestern Counties, by S. S. Johnson, M. V. Denny, and D. C. Le Van, Virginia Division of Mineral Resources: Mineral Resources Rept. 6, 186 p., 11 fig., 1966.

Analyses of Clay and Related Materials--Eastern Counties, by S. S. Johnson and M. E. Tyrell, Virginia Division of Mineral Resources: Mineral Resources Rept. 8, 232 p., 9 figs., 1967.

Analyses of Clay, Shale, and Related Materials-Southern Counties, by P. C. Sweet, Virginia Division of Mineral Resources: Mineral Resources Rept. 12, 183 p., 12 figs., map, 1973.

Clay-Material Resources in Virginia, by P. C. Sweet, Virginia Division of Mineral Resources, Mineral Resources Rept. 13, 56 p., 1 map, 1976.

Virginia Clay Material Resources, by P. C. Sweet, Virginia Division of Mineral Resources: Publication 36, 178 p., 1982.

COPPER

Geology and Mineral Resources of the Gossan Lead District and Adjacent Areas in Virginia, by A. J. Stose and G. W. Stose, Virginia Division of Mineral Resources: Bull. 72, 233 p., 1957.

Base- and Precious-metal and Related Ore Deposits of Virginia, by G. W. Luttrell, Virginia Division of Mineral Resources, Mineral Resources Rept. 7, 167 p., 1 pl., 1 table, 1966.

Notes on Some Abandoned Copper, Lead, and Zinc Mines in the Piedmont of Virginia, by James L. Poole, Virginia Division of Mineral Resources, Virginia Minerals, vol. 20, no. 2, 1974.

Abandoned Copper Mines and Prospects in the Virgilina District, by Palmer C. Sweet, Virginia Division of Mineral Resources, Virginia Minerals, vol. 22, no. 3, 1976.

Metallic Mineralization in the Blue Ridge Province of Virginia, by Palmer C. Sweet and Stephen C. Bell, in Contributions to Virginia Geology - IV, Virginia Division of Mineral Resources, Pub. 27, p. 39-53, 1980.

CRUSHED STONE

Sources of Aggregate Used in Virginia Highway Construction, by E. O. Gooch, R. S. Wood, and W. T. Parrott, Virginia Division of Mineral Resources, Mineral Resources Rept. 1, 65 p., 1960.

DIATOMACEOUS SEDIMENTS

Diatomaceous Sediments in Virginia, by R. F. Pharr, Virginia Division of Mineral Resources, Virginia Minerals, vol. 11, no. 3, 1965.

FELDSPAR

Pegmatite Deposits of Virginia, by A. A. Pegau, Virginia Geol. Survey Bull. 33, 123 p., 20 pls., 11 figs., 9 tables, 1932.*

Mica Deposits of the Southeastern Piedmont, by U. S. Geological Survey Staff, U. S. Geol. Survey Prof. Paper 248, 1952.*

Mica and Feldspar Deposits of Virginia, by W. R. Brown, Virginia Division of Mineral Resources, Mineral Resources Rept. 3, 195 p., 24 pls., 17 figs., 9 tables, 1962.

Feldspar Resources and Marketing in Eastern United States, by S. A. Feitler, U. S. Bureau of Mines Info. Cir. 8310, 41 p., 1967.*

GEM STONES

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Geology of the Titanium and Apatite Deposits of Virginia, by T. L. Watson and Stephen

Taber, Virginia Geol. Survey Bull. 3-A, 308 p., 37 pls., 33 figs., 1913.*

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APPENDIX III: ADDRESSES OF REGULATORY AGENCIES

State

Division of Mined Land Reclamation
Minerals Other Than Coal
P. O. Box 4499
Lynchburg, Virginia 24502

Phone: 804/239-0602

Division of Mined Land Reclamation
622 Powell Avenue
Big Stone Gap, Virginia 24219

Phone: 703/523-2925

Division of Mines
219 Wood Avenue
Big Stone Gap, Virginia 24219

Phone: 703/523-2925

Department of Labor and Industry
Research and Statistics
205 North Fourth Street
Richmond, Virginia 23219

Phone: 804/786-1474

Air Pollution Control Board
801 Ninth Street Office Building
Richmond, Virginia 23219

Phone: 804/786-6035

State Water Control Board
2117 N. Hamilton Street
Richmond, Virginia 23230

Phone: 804/257-0056

Department of Highways and Transportation
1221 East Broad Street
Richmond, Virginia 23219

Phone 804/786-2801

(Applicable district and residency offices may also supply permits)

Marine Resources Commission
2401 West Avenue
Newport News, Virginia 23607

Phone: 804/247-2200

Federal

U. S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510

Phone: 804/441-3601

U. S. Army Corps of Engineers
Huntington District
502 8th Street
Huntington, West Virginia 25701

Phone: 304/529-5253

APPENDIX IV: MINERAL RESOURCES SECTION OF THE FAIRFAX COUNTY 1983 COMPREHENSIVE PLAN

MINERAL RESOURCES

The Fairfax County ordinance was amended by the Board of Supervisors in 1961 to establish a natural resource overlay district which recognized, protected and authorized the extraction of sand and gravel resources. The major emphasis of the natural resource overlay district was to allow for the extraction of major sand and gravel resources in the Franconia/Lehigh area. An additional purpose was to reduce the negative impact of truck traffic, noise, visual and air pollution on neighboring subdivisions and secondary roads.

In 1971, the natural resource overlay district was amended to include crushed stone resources as well as sand and gravel. Additional changes included a five year extension of the Franconia/Lehigh natural resource overlay zone. During 1976, all existing and future sand and gravel extraction permits were terminated. Crushed stone extraction is still permitted pending the rezoning of land to a natural resource overlay district and the approval of a Group I special use permit.

The need for construction materials in Fairfax County is increasingly apparent from sharply rising construction costs, despite the fact that many of the needed rock and mineral resources are available within the County.[1] If these resources are to be developed with an attendant savings in construction costs, there must be both an awareness of the extent of environmental disruption accompanying their development, and a balancing of that disruption against the higher costs of imports. A decision to use or not use an available resource depends on many factors, including the possible environmental disruption to air, water, the landscape and local communities. However, wise planning and regulation in advance of extraction can reduce or avoid anticipated damages. As urbanization expands into rural or undeveloped areas, potential mineral deposits may be preempted, unless such deposits are recognized and preserved in the land use planning process. Extraction of rock or sand and gravel may be only a temporary stage in efficient land use planning. After extraction, the land can be restored to agriculture, used for recreational areas, building sites, or possibly solid waste disposal.

If the option of ensuring the future availability of construction materials in Fairfax County is selected, a series of actions is required in advance of extraction. First, future needs must be forecast and analyzed; second, potential resource sites of adequate size must be identified, inventoried, classified and ranked; third, resources sites with economic potential must be protected from preemptive land uses, although interim temporary uses are possible pending future extraction; and fourth, reclamation plans for sites of depleted resources should consider sequential land uses (such as for recreation or solid-waste disposal) that take advantage of the topographic, hydrologic, and geologic characteristics of each site. This analysis should consider the need to reserve adequate space for processing plants, access roads, buffer zones, and utility corridors for high-load electrical lines. Effective protection of resources presently remote from urban acres may depend on the preparation of land use plans long before development is scheduled to occur.

The rock and mineral resources of Fairfax County are used as sources for construction material, highway fill and building stone.[2] The map titled Potential Mineral Resources shows the rock and mineral resources available within the County. Past and present quarries, pits, and mines are also shown on the map and keyed to a locality list. During 1975-76 diabase was quarried for rip-rap, fill and crushed stone; granite was quarried for aggregate, crushed stone, rip-rap, and fill; and sand and gravel were extracted for construction uses. Resources necessary for future construction include adequate quantities of crushed stone and sand and gravel at or near the surface and located close to the area of use. The County has large reserves of some industrial materials, but new extraction sites may be needed to fulfill economically the requirements of future construction.

Minor deposits of metallic or nonmetallic minerals are distributed throughout Fairfax County, but these occurrences are mainly of historical, mineralogical, or geological interest.

Listed below are more detailed descriptions of the rock and mineral resources found in Fairfax County. The major categories are crushed stone, sand and gravel, and minor deposits of historic interest; within each category, the resources are listed in terms of relative importance as a viable resource.

Crushed Stone

Diabase

Diabase, a dark colored igneous rock suitable for crushed stone, underlies much of western Fairfax County and extends into adjacent Loudoun County. Diabase makes excellent aggregate because it is tough, has uniform texture, and is resistent to chemical weathering. Crushed diabase is used principally as binder-filler for asphalt paving, as base course for highways, for road metal, and for concrete aggregate.

The near-surface part of the spoon-shaped diabase body that surrounds Herndon covers approximately six square miles in Fairfax County, about 60 percent of which is partly urbanized. About 40 percent of a similar body near Centreville, an area that covers approximately eight square miles in Fairfax County, is urbanized, partly urbanized or otherwise committed to parkland and other uses (Locality 1). A square mile area excavated to a depth of 50 feet contains about 130 million tons of diabase suitable for crushed stone or about 35 years supply at current rates of consumption in the County.

Baked Zone

The baked zone forms a belt of altered sedimentary rocks surrounding the diabase rock bodies. The baked zone averages about one-half mile wide and is present along the inner and outer margins of the diabase bodies at Herndon and Centreville. Baked silt-stone and shale have been locally used as a source of fill and roadbed material, and several quarries in Loudoun County produce part of their crushed stone output from this zone. However, it should be noted that engineering tests are required at each potential quarry site to ascertain whether required characteristics are present in the rocks.

Granite

Granite is quarried from the moderately foliated Occoquan Granite near Occoquan, Virginia (Locality 2). In 1976 the quarry covered 10 acres, was 350 feet (107m) deep, and had an anticipated life of about 10 years at current rates of production. The chief use is for aggregate, crushed stone, rip-rap and fill. Similar granites crop out near the surface in southern Fairfax County, but core-drilling and engineering tests are required to ascertain acceptable quality. Much of the area underlain by granite is mantled by a blanket of saprolite (weathered rock) as much as 100 feet (30m) thick.

Serpentinite

Serpentinite was formerly quarried for crushed stone and aggregate at a small, long-abandoned quarry on Leigh Mill Road near Great Falls (Locality 5). Similar material quarried in nearby Montgomery County, Maryland, was the chief source of crushed stone in 1975. In Fairfax County, serpentinite occurs chiefly in narrow, elongate tabular bodies; the largest of these, near Reston, is partly urbanized. Most narrow bodies and the borders of the large bodies are sheared and may contain fibrous asbestos. Therefore, they are unsuited as a major future source of crushed stone.

Building Stone

Abandoned quarries in schist, gneiss, greenstone and granite are widely scattered throughout Fairfax County (Localities 4, 6, 7). The bedrock exposed in the quarries is foliated and jointed, characteristics that undoubtedly facilitated quarrying. The rock was reportedly used locally for flagstone, building stone, veneer, slate, fill and rip-rap. Extensive reserves of rock similar to that formerly quarried remain at shallow depth, but many accessible sites are now used as streamside parks and for residential developments. Extensive areas of Occoquan granite are readily accessible in southern Fairfax County, should greater use of this attractive stone become desirable.

Sand and Gravel

Upland and Coastal Plain Deposits

Sand and gravel were formerly dug from numerous pits in the eastern part of the County. The upland area formerly blanketed by extensive sand and gravel deposits, which exceed 20 feet in thickness, was about 33 square miles. Gravel and sand were removed from about 2 square miles and about 25 square miles in the deposits are urbanized, leaving about 6 square miles of material potentially available for use.

In some areas beneath these upland sand and gravel deposits, the Cretaceous-age (a million years old) sand and pebbly sand deposits of the underlying Coastal Plain sediments were formerly dug for local use as construction materials.

Sand-sized quartz-rich material that formed as saprolite on deeply weathered Occoquan granite has been dug at Fort Belvoir west of Accotink Creek. Large areas underlain by similar material remain.

Alluvium

Sand and gravel deposits of limited extent are present along the Occoquan and Potomac Rivers, Difficult Run and Pohick, Popes Head, and Accotink Creeks. The alluvial deposits probably average 20 feet thick and contain much clay and silt. Clean, quartz-rich, sandy alluvium is common in stream deposits draining areas underlain by Occoquan granite, as in South Run and Sandy Run. Any plan to extract these deposits must be weighed against the scenic values, recreational uses, and effects on surface water quality of the rivers and creeks. Perhaps more importantly, these deposits may contain a significant volume of clean, potable, shallow groundwater which is relatively secure from airborne pollutants and possibly suitable as an emergency supplemental supply of drinking water.

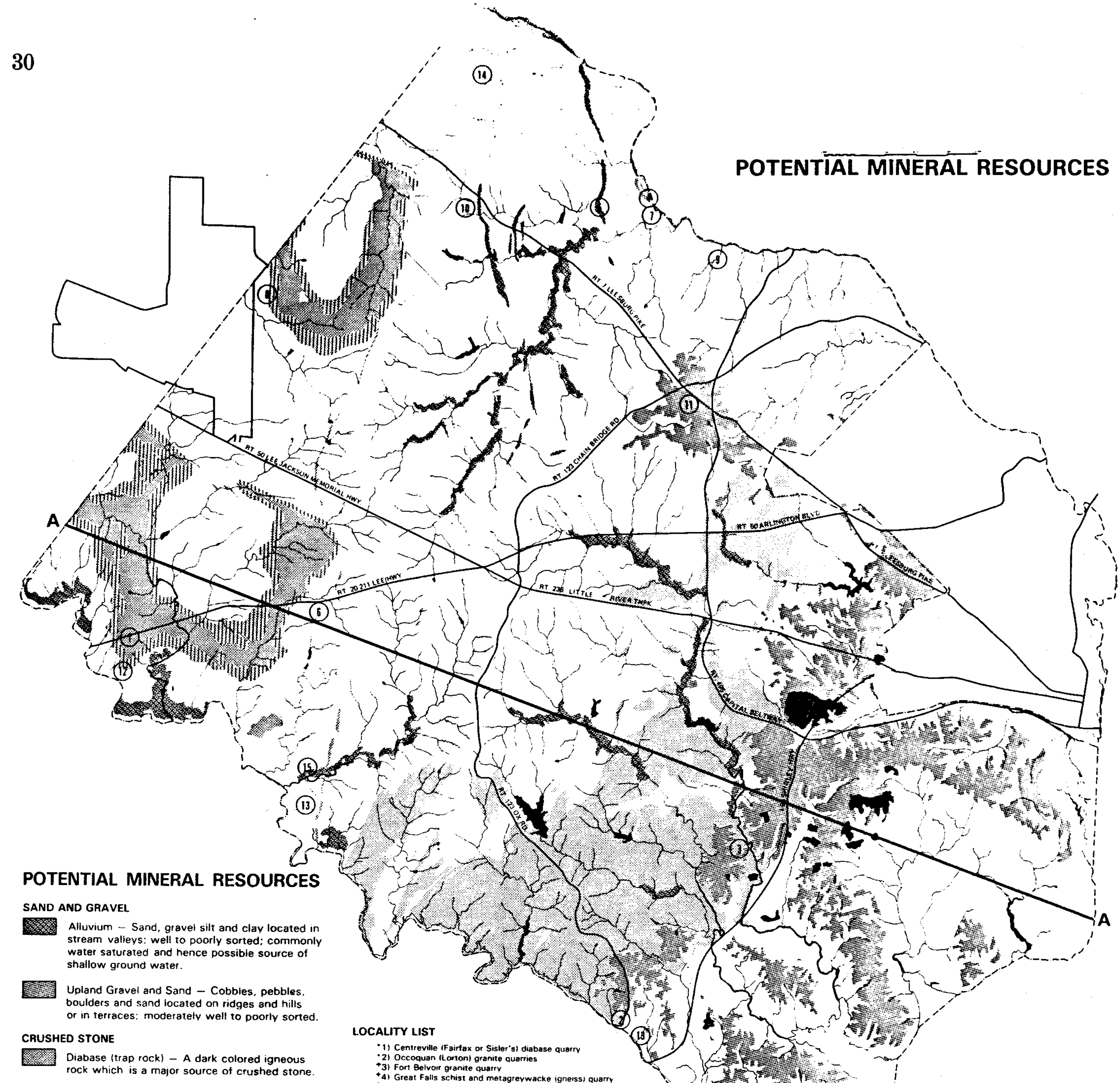
[1] "Sand and gravel is a low cost commodity, but its transportation cost is high. Generally, the truck transportation charge for a 15 to 20 mile haul equals the cost of a ton of gravel at the plant. This illustrates the importance of having sand and gravel extraction operations close to urban areas, where most construction is taking place." *Natural Features of the Washington Metropolitan Area*, Metropolitan Washington Council of Governments, January 1968; p.10.

[2] The following statistics indicate the quantities of sand and gravel used in contemporary construction:

- 95 percent of asphalt is sand and gravel.
- 70 percent of concrete is sand and gravel.
- 90 percent of a concrete block is sand and gravel.
- An average house uses 50 to 100 tons of sand and gravel.
- A subdivision street one block long uses 400 to 600 tons of sand and gravel.

Natural Features of the Washington Metropolitan Area; Metropolitan Washington Council of Governments, January 1968; p. 10.

POTENTIAL MINERAL RESOURCES



POTENTIAL MINERAL RESOURCES

SAND AND GRAVEL

- Alluvium – Sand, gravel silt and clay located in stream valleys; well to poorly sorted; commonly water saturated and hence possible source of shallow ground water.
- Upland Gravel and Sand – Cobbles, pebbles, boulders and sand located on ridges and hills or in terraces; moderately well to poorly sorted.

CRUSHED STONE

- Diabase (trap rock) – A dark colored igneous rock which is a major source of crushed stone.
- Baked Zone – Fused shale, sandstone, conglomerate and siltstone formerly used locally as source of crushed stone.
- Serpentinite – Potential source of road metal
- Granite – Quarried for building stone, fill and rip-rap; saprolite locally used as source of sand.
- Gravel pit, active or abandoned (ground disturbed by extracting gravel).
- Locality number keyed to locality list.

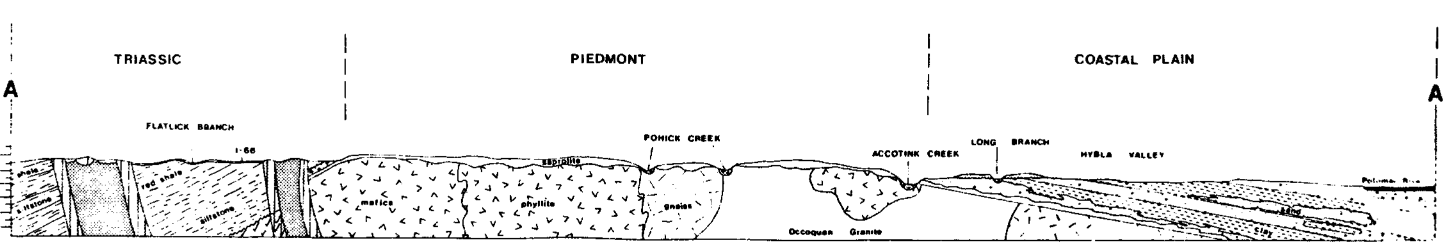
LOCALITY LIST

*1) Centreville (Fairfax or Sisler's) diabase quarry
*2) Occoquan (Lorton) granite quarries
+3) Fort Belvoir granite quarry
+4) Great Falls schist and metagreywacke (gneiss) quarry
+5) Leigh Mill serpentinite quarry
+6) Sister's quarry
+7) Difficult Run quarry
+8) Theodora copper mine
+9) Kirk (Bullneck) gold mine
+10) Jenkins Farm copper and soapstone mine
+11) Tysons Corner gravel outlier
+12) Clay (Triassic potential for brick or tile)
+13,14) Clay (Schist, slate or phyllite, potential for common brick)
+15) Pyrite (fool's gold) and other sulfides

* Active quarry (1976)
\+ Accessible mine, pit, prospect or quarry (1976)

Source: Map Showing Mineral Resources of Fairfax County, Virginia – Availability and Planning for Future Needs. A. J. Froelich; USGS Open File Map No. 76-660; 1976

SCHEMATIC GEOLOGIC AND MINERAL RESOURCES CROSS SECTION FAIRFAX COUNTY, VIRGINIA



SCALE: HORIZONTAL 1:48,000
VERTICAL EXAGGERATION 8X

Minor Deposits of Historic Interest

Gold

Gold was mined underground from quartz veins in schist bedrock and saprolite and from alluvial placer workings at the Kirk Mine on Bullneck Run (Locality 9) between 1890 and 1939. Gold flakes were panned from stream gravel in Bull Run about 300 meters south of Route 66.

Copper

Copper carbonates, silicates, and sulfides were mined on a small scale in the 1880's at the Theodora copper mine near Herndon (Locality 8). Other minor disseminated copper occurrences are common in the baked zone adjacent to diabase intrusives near Chantilly, but none are known to have been mined. Malachite is associated with serpentinite at Jenkins Farm Prospects (Locality 10).

Iron

Various forms of iron ore are magnetite, hematite and pyrite (fool's gold). Magnetite is reportedly associated with chlorite and chromite in serpentinite near Dranesville and in the abandoned quarry (Locality 5) on Leigh Mill Road. Pyrite and other sulfide minerals are disseminated in metamorphic rocks exposed in the railroad cut near Clifton (Locality 15).

Talc

Talc, derived from soapstone, was prospected and mined locally at the Jenkins Farm Prospects (Locality 10) and near Turkey Run north of George Washington Memorial Parkway. Talc is associated with serpentinite and chrysotile asbestos, as well as chlorite and minor iron and copper minerals.

Clay

Commercial clay deposits or potential deposits are not common in Fairfax County. The Cretaceous-age Potomac group of the Coastal Plain contains abundant clay beds, but they are highly expansive and unsuited to brick manufacture due to their high montmorillonite content, montmorillonite being a mineral which swells when wet and shrinks when dry. Fresh and weathered red Triassic shale, which may be suitable for light-weight aggregate or in the manufacture of common brick, terra cotta pipe, and tile products, is fairly common south of Dulles Airport. Specific localities sampled are near the I-66 crossing of Bull Run (Locality 12). Some areas of saprolite on slate and schist may provide clay of satisfactory characteristics for common brick (Localities 13, 14). Clay derived from deep weathering of the Quantico slate was formerly dug near Lorton.

ENVIRONMENTAL GEOLOGY STUDY OF FAIRFAX COUNTY

The U.S. Geological Survey environmental geology study is a multifaceted project designed to provide timely geologic and hydrologic information in a form useful to planners, developers, engineers, decision makers, and citizens concerned with the County's earth environment. From its inception in July 1974, the project has involved cooperation between some of the United States Geological Survey staff and the Fairfax County Office of Comprehensive Planning staff. In addition, the U.S. Geological Survey has contributed very significant amounts of funding and professional man-years to the study. Upon completion of the project in 1977, a series of maps at 1:48,000 (the County planning scale—about one inch = ⅔ mile) will be issued to show earth science factors important for rational planning and management of the environment. Types of maps include landforms, geology, surface materials, base of saprolite (depth to bedrock), mineral resources and those related to aquifer recharge and groundwater supply.

Much of the geologic work to date has involved assembly and compilation of available geologic soils and water-well data; however, new geologic field work was recently completed by three teams of professional geologists in all parts of the County, as existing information was inadequate for environmental analysis. Selected preliminary quadrangle maps at the 1:24,000 compilation scale have been released to open-file as completed. To date twenty-four such maps or studies have been turned over to the Fairfax County Department of Environmental Management, the principal depository.

The study is also utilizing new approaches to topical problems not systematically addressed in this area before, such as shallow refraction seismic surveys and electrical resistivity surveys to determine depth to hard rock and thickness of overburden or depth to groundwater. Auger and core drilling and engineering tests of recovered surface and subsurface materials are underway. New and very detailed aeromagnetic and aeroradioactivity surveys have been flown to aid in the geologic analysis. Laboratory analysis of samples includes engineering tests, X-ray diffractometry of clays, quantitative mechanical analysis of sands, thin-section preparation, and petrographic examination of saprolite and crystalline rocks.

DEVELOPMENT HAZARDS

The issue of physical hazards include those environmental constraints of natural systems which are either inherently hazardous to human life or hazardous to human life and health by specific human action. If significantly altered by land development, both types produce undesirable social and economic costs. Major hazards to, or constraints on, development which have been identified in Fairfax County include floodplains, wetlands, slippage prone shrink-swell soils, highly erodible soils (especially those on steep slopes), septic limitations of soils, and aquifer recharge areas. Countywide maps of these features are located in the map section of this plan.

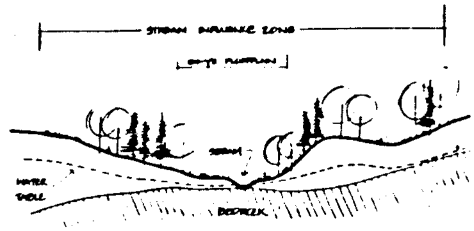
Land with these conditions is more costly to develop than unconstrained land and therefore it is often the last vacant land to be developed in any given area. However, as population increases, pressure to develop even these constrained lands will mount such as the heavy siltation of Lake Accotink and the Occoquan Reservoir, or the structural damage caused by construction on slippage soils. A detailed geologic survey now under way in Fairfax County will facilitate not only the avoidance of these hazard areas, but also the proper location of hazardous land uses like sanitary landfills and sludge disposal sites.

Because of their radically different physical properties, planning responses to these hazards will naturally differ. An issue-by-issue discussion follows for each of the hazard features.

Floodplain and Stream Influence Zones

Because development on floodplains is hazardous, they are not shown for any residential, commercial, or industrial land uses on the area plans. Adjacent to these areas, however, are stream influence zones. These are arbitrarily defined as areas within 300 horizontal feet of either side of a stream, or the 100-year floodplains, whichever is greater (recognized authorities in planning hydrology suggest a distance of between 50 and 300 feet for a stream influence zone).

A stream influence zone differs from the stream valley (see glossary) only in scope. The latter, delineated primarily on the basis of topography, is the more comprehensive, whereas the stream influence zone (along with floodplains) may be thought of as the most sensitive area within a stream valley. As suggested previously, this zone can be delineated once additional physical characteristics (geologic, soils, vegetation) are analyzed.



Specific application of the concept in Fairfax County will reflect site conditions such as depth to and slope of bedrock, soil types, slope, and vegetative cover, as indicated by the illustration. These conditions will be mapped upon completion of several research contracts under way in the County. Development within stream influence zones may be allowable given considerable care to minimize vegetation removal, grading and filling. Again, the risk of adverse impacts on water quality motivates the suggestion of this set of development controls.

Wetlands

Wetlands are a unique, valuable, and irreplaceable natural resource, serving as a habitat for mammal species of spectator value, and for many species of fish and waterfowl. They also serve to moderate extremes in water flow, aid in the natural purification of water, and maintain and recharge groundwater resources. Their definition is a hydrologic one. Consequently, virtually no development which alters the hydrologic regime of these areas can be permitted if they are to be preserved. Planning these areas for parklands, as in Sectors MV2 and MV6 of Area IV, has been recommended and generally is an acceptable method for wetland preservation.

Soils

Slippage-prone shrink-swell soils are evaluated for precise project hazard in the County's Department of Environmental Management, using the guidelines for the preparation of geotechnical studies. Modifications of the land use recommendations, restriction of development or new engineering requirements for foundations constructed in or near these areas may be mandated to avoid additional structural and/or yard damage.

Steep Slopes

Steep slopes with or without erosion-prone soils require that the utmost erosion control measures be enforced during development in accordance with the erosion-sediment control ordinance and tree ordinance. This is especially important since these slopes generally coincide with water features thereby almost guaranteeing excessive sedimentation. The planning response has been to guide low-density development to these areas so as to minimize the number of projects which could adversely impact stream quality.

Faults

A fault is a zone of broken material between differing rock strata along which vertical, diagonal and/or horizontal movement has occurred. In Fairfax County, faults of relatively small displacement, trending north-northeast, are common along the contact or boundary between the Piedmont and Triassic lowland geologic provinces. For example, a fault has been identified approximately one mile due north of the Reston Avenue — Baron Cameron Avenue intersection; another has been located near the U.S. Geological Survey National Center. Although the faults in this area are not active, they contain zones of weakness, i.e., gouge zones where rocks acted on each other (grinding, crumbling) during the faulting process. The size of these gouge zones varies depending on the rock types. Even so, because bearing capacity is very

APPENDIX V: ZONING STATUS FOR MINERAL EXTRACTION

The following table gives the status as of February 1984, of zoning in each county, the zoning districts in which mineral extraction is allowed, and whether or not a special or conditional use permit is required for mineral extraction.

Zoning District - designations for specific zones in which extraction can take place are listed. Numbers for zoning districts relate to the intensity of land use. Generally the larger the number the more intense the use.

Ag	- agricultural use
Res.	- agriculture residential, very low density
AOC	- agricultural open space conservation
B	- general business
C	- conservation district, open space preservation
F	- forestal district
FOC	- forestal open space conservation
I, Ind.	- industrial district
M, Mfg.	- manufacturing district
R, Res.	- residential district

Permitted Use for Mineral Extraction

County	Existing Zoning Ordinance	Zoning District	Special or Conditional Use Permit	Other
Accomack	yes	any zone	yes	
Albemarle	yes	any zone where compatible		Nat. Resource Overlay
Alleghany				
Amelia	yes	Ag., Mfg.	yes	
Amherst	yes	Ag.,Mfg.	yes	
Appomattox				
Arlington	yes			no provisions for extraction
Augusta	yes	A	yes	
Bath	yes	Ag.-1, Ag.-2	Ag.-2 only	
Bedford				
Bland				
Botetourt	yes	M-3		
Brunswick				
Buchanan				
Buckingham				
Campbell				
Caroline	yes	Ag.-1-Mfg.-1	yes	
Carroll				
Charles City	yes	A-1, M-l	yes	
Charlotte				
Chesterfield	yes	Ag, M-2, M-3	Ag, M-2 only	
Clarke	yes	AOC, FOC	yes	
Craig	yes	M-1		
Culpeper	yes	Mfg.	yes	
Cumberland	yes			no provisions for extraction

Dickenson				
Dinwiddie				
Essex	yes	A-1, A-2	yes	
Fairfax	yes			mineral extraction overlay district
Fauquier	yes	Rural zones	yes	
Floyd				
Fluvanna	yes	I-2	yes	
Franklin	yes	C	yes	conservation district with permit
Frederick	yes			extractive mfg. and hist. districts by right
Giles				
Gloucester				
Goochland	yes	A-1, A-2, M-2, F-1	A-2, M-2, F-1 only	
Grayson				
Greene	yes	C-1, A-1, M-2	yes	
Greensville				
Halifax				
Hanover	yes			conditional use in all districts
Henrico	yes	A-1, M-1, 2, 3	yes	conservation districts by special use permit
Henry				
Highland	yes	C-1, A-2	yes	possible in A-1 with development plan and public hearing
Isle of Wight	yes			borrow pit ordinance
James City	yes	A-1, A-2, M-2	yes	
King George	yes	Mfg.		
King and Queen				
King William	yes	Ag., Res., B-2		

Lancaster	yes	A-2	yes	
Lee				
Loudoun	yes	A-10, A-3, R-1, C-1, I-1	A-10, A-3 only	
Louisa	yes	Ag., Mfg.	yes	
Lunenburg				
Madison	yes	M-2	yes	
Matthews				
Mecklenburg				
Middlesex				
Montgomery	yes	A-1, M-1	M-1 only	
Nelson	yes	A-1, C-1	C-1 only	
New Kent	yes	M-2	yes	
Northampton	yes	Ag., Res.	yes	
Northumberland	yes	A-1, M-1, R-2	yes	
Nottoway	yes	Ind.		
Orange	yes	Ag.	yes	
Page				
Patrick				
Pittsylvania	Draft			
Powhatan	yes	A-1, M-1	yes	
Prince Edward				
Prince George	yes	Ag, M-2	M-2 only	
Prince William	yes	A-1, M-1	yes	
Pulaski				
Rappahannock	yes			zoning ordinance being rewritten
Richmond				
Roanoke	yes	M-3		
Rockbridge	yes	A-1, A-2		
Rockingham	yes	A-1	yes	
Russell				
Scott				
Shenandoah	yes	M-1		
Smyth				
Southampton	yes	M-2	yes	
Spotsylvania	yes	Ag-1, Mfg.-1	yes	
Stafford	yes	M-2		
Suffolk City	yes	M-1, 2	yes	
Surry	yes	Ag., Res.	yes	
Sussex				
Tazewell				

Warren	yes		yes	allowed at present sites
Washington	yes			
Westmoreland	yes	A-1, C-1, M-1	A-1, C-1 only	
Wise				
Wythe				
York	yes			only by special use permit, zoning district not specified