COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
1981

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

COVER PHOTOS

FRONT: Silent remnants of Colorado's once prosperous fluorspar industry, the mill and mine at Wagon Wheel Gap, Mineral County, the state's fourth largest district. BACK: Ladders and scaffolding remain precariously perched on the upper walls of the famous Colorado Yule marble quarry, Gunnison County. This celebrated building stone found its most distinctive applications in the Colorado State Capitol, the Lincoln Memorial, and the Tomb of the Unknown Soldier.

MAP SERIES 17

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

Compiled by
Stephen D. Schwochow
1981

Colorado Geological Survey
Department of Natural Resources
State of Colorado

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INTRODUCTION

Under its legislated duty to "inventory and analyze the state's mineral resources as to quantity, chemical composition, physical properties, location, and possible use," the Colorado Geological Survey in 1975 began a series of statewide mine and resource inventories that now includes coal, oil and gas, geothermal, uranium, thorium, and vanadium, with other metallics in progress. As the latest in this series, Map Series 17 shows the distribution and types of construction material and industrial mineral mining operations, collectively known as the nonfuel nonmetallics. Processing and manufacturing facilities have been added as ancillary activities.

Besides their "basic-data" contribution, the maps should help demonstrate 1) the amazing variety of nonmetals that have been mined in Colorado, 2) the very widespread distribution of these operations compared to metallics and fuels, and 3) the interrelationship of construction materials production, transportation routes, and centers of growth and population.

Methods, Products, Accuracy

This 2.5-year compilation was completed primarily by airphoto examination with the following dates and areas of coverage:

AMS	7/53 to 10/55	(statewide except San Juan Mtns.)
	8/58 to 8/60	(San Juan Mtns.)
Mark Hurd	10/70 to 7/73	(Front Range corridor and west 1/4 of state)
USGS	6/75 to 10/77	(eastern 2/3 of state)

Major sources of information were found in publications of the Colorado Geological Survey, U.S. Geological Survey, U.S. Bureau of Mines, Rocky Mountain Association of Geologists, Colorado Scientific Society, and Colorado School of Mines.

Sites along most major transportation routes and in areas of highest concentration were verified in the field. Plant locations were found through local telephone directories and by serendipitous discoveries in the field.

County and operator card files at the Colorado Division of Mined Land Reclamation supplied the names and locations of mines active in the last several years and those for which permits had been applied for. Because I found no convenient way to determine which applications had been recently approved, the maps show those under application through 1980 and may include those that have been permitted but not yet in production and others that are still pending.

Mine location first were plotted on standard USGS 7.5' and 15' topographic maps and then transferred onto the sixteen 1:250,000-scale AMS 1°x2° base maps that cover the State of Colorado (Figure 1). The 1:100,000-scale Front Range Urban Corridor base map and the 1:24,000-scale Pueblo insert map cover important areas where the concentration of operations warranted larger map

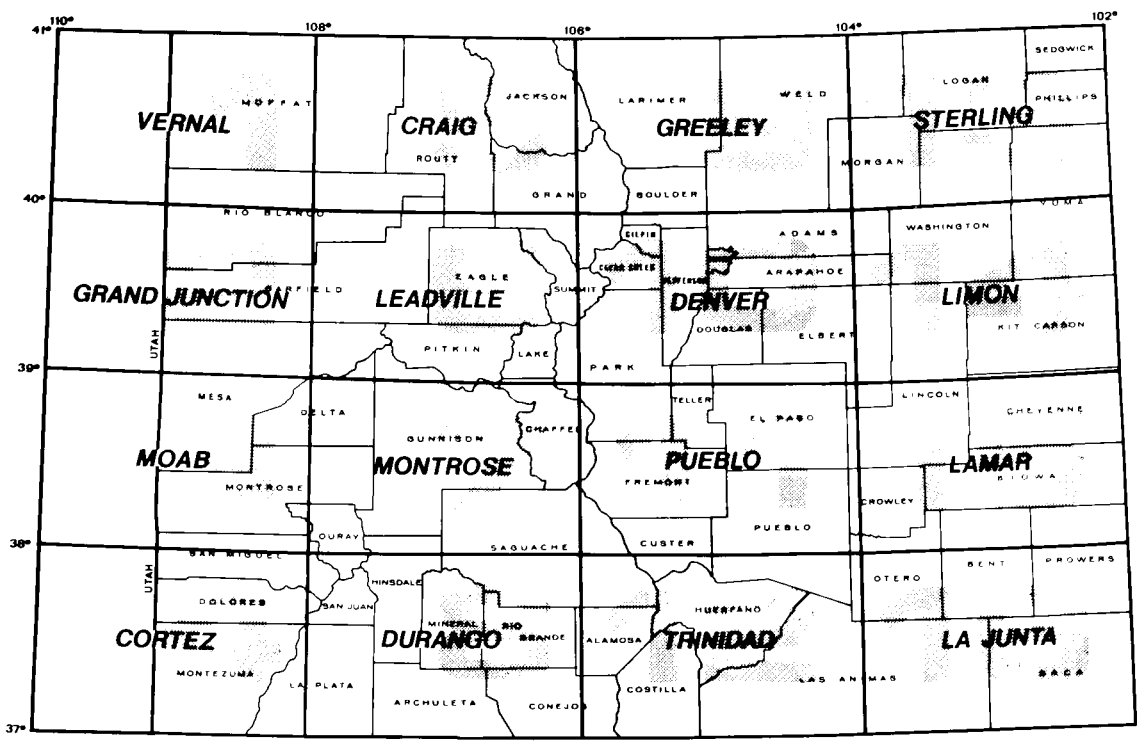

FIGURE 1. Index to 1°x2° quadrangles and mine inventory maps, showing sheet names and plate numbers.

scales. Because of the plotting accuracy at the original map scale, sites on the smaller scale final maps should be accurate to the nearest quarter-quarter section. One may note some peculiarities where the older AMS base maps do not reflect such recent cultural changes as new highways, reservoirs, stream course changes, and political boundary changes. As a result of differences in section and township lines between the larger and smaller map scales, some sites necessarily have been adjusted at the expense of the land grid to reflect their true cultural locations, e.g. lying on the appropriate side of a road or stream.

A sand and gravel operation flagged with a "?" usually indicates that a probable operation was detected on the airphotos but not field verified. With other kinds of operations, the mark most often means an operation exists, but the commodity is uncertain. As some rock formations yield more than one material, even a geologic map could not always verify the product. More sites with the "?" could have been verified had access been open or had field checking been done in the immediate vicinity. With the obvious constraint in covering an entire state the size of Colorado, areas for field checking had to be selected carefully, and some unfortunately had to be passed over. Some mines, especially old ones, simply could not be located or plotted at all (without covering the ground on foot) with the sketchy information available. In the commodity discussions I have been conscious not to emphasize how many of these have been omitted.

Plant sites theoretically are permanent locations, but in the case of asphalt and ready-mixed concrete, batching plants can be moved depending on the location and schedule of certain road and construction jobs. Although I have attempted to show what appeared to be permanent batching sites, neither I nor the reader can assume that all of those shown on the map will remain there. In a few cases, such as the brick plants, the plants had historical or statistical importance but through the years were destroyed, dismantled, or converted. These have been plotted at or near the original sites (where determinable) to commemorate their one-time existence and contribution.

At first glance the number of operations shown on these maps appears startling, but readers should remember that all of them certainly are not in production today. The majority are either abandoned, inactive, or reclaimed.

Nothing shown should be interpreted as evidence of operating status, compliance or noncompliance with any government regulations, other than those occasionally cited in the commodity discussions or, as explained above, currently under application.

Final tally of all plotted mines and "?" sites (plus or minus a few) shows that Colorado has 355 crushed-rock quarries, 388 dimension stone quarries, 342 clay mines, 182 pegmatite mines, 195 miscellaneous industrial mineral operations, and 5,712 sand and gravel pits. The 281 plants added in give a total of 7,455 plotted sites. One might add another 1 to 3 percent for those sites that could not be located.

Acknowledgments

I wish to thank the many mine and plant operators, ranchers, landowners and others whom I encountered in the field and on the telephone who altogether proved most helpful and cooperative in this project. I would like to acknowledge CGS staff members, Etta Norwood and Cheryl Brchan, for this publication's drafting and production, and Rebecca Nelson, Lori Thomas, and Valerie Taylor for preparation of the final manuscript. Lastly, special appreciation goes to the staff of the Colorado Division of Mines for their patience and frequent assistance in locating valuable file data and library materials.

The following commodity discussions are designed to offer the reader brief introductions to the geology, production history, uses, and importance of Colorado's nonmetallic mineral resources.

C O M M O D I T Y D I S C U S S I O N S

CONSTRUCTION MATERIALS

Sand and Gravel

Sand and gravel head the list of Colorado nonmetallics in tonnage produced and value of production. They are the only mineral commodities produced in every county of the state. Compared to Colorado's other principal resources,

sand and gravel rank fourth in value behind molybdenum, oil and gas, and coal. 1973 was a peak production year nationwide for many nonmetals, especially sand and gravel, and Colorado's contribution amounted to 33,767,000 tons valued at $45.5 million. Production levels dropped during the economic setback in 1974-76 but since have rebounded and fluctuated in response to the nation's and region's building industry (Figure 2).

All residential, industrial, and highway construction requires large volumes of gravel and stone. Of the 97 percent of all sand and gravel used for construction, most is required for base course, asphaltic aggregate, and surface treatment in the construction and maintenance of streets and highways. Next is concrete aggregate for use in all basic building and heavy construction, and major highways. Following structural fill, the other main uses include concrete products, ballast, plaster and gunite sand, and snow/ice

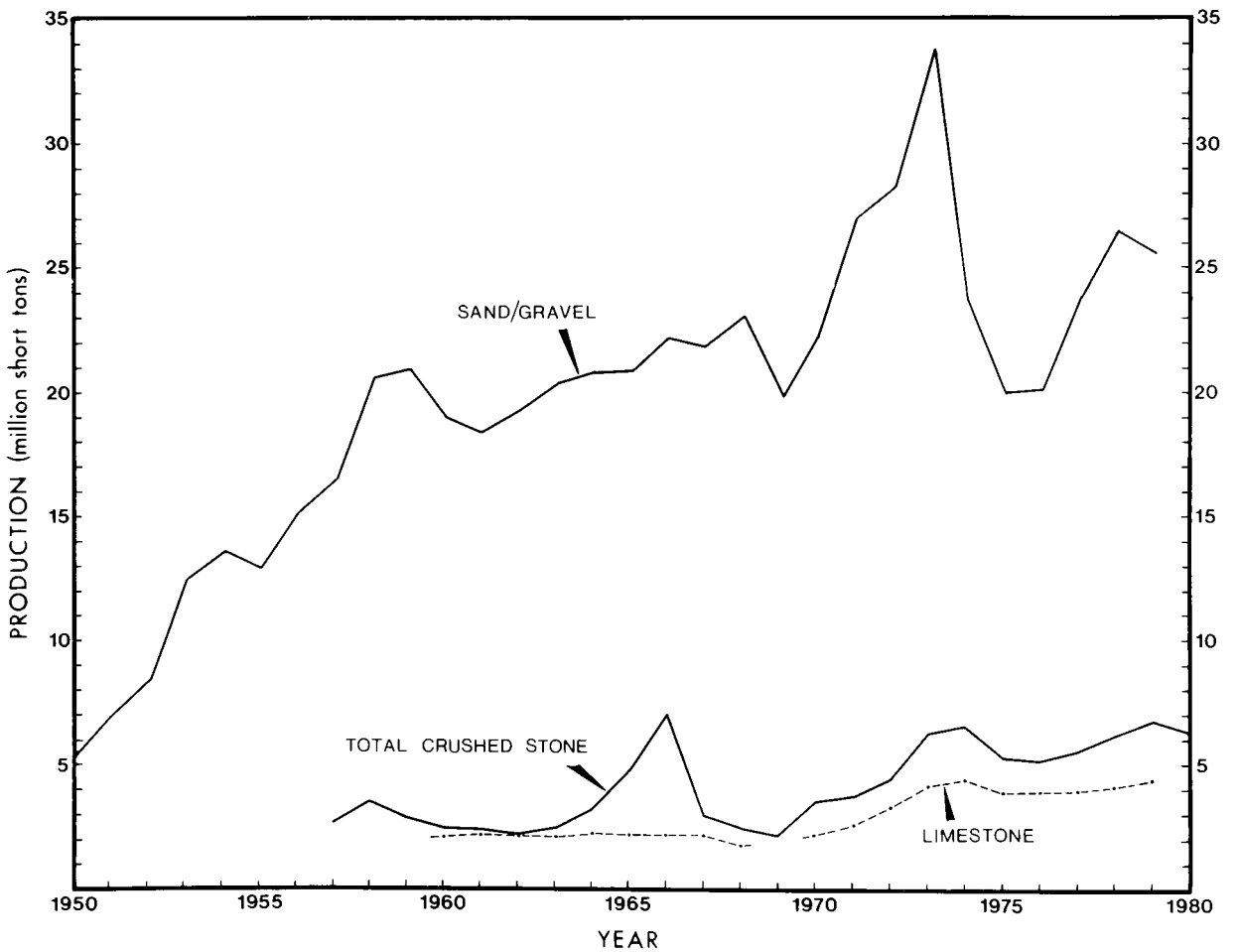

FIGURE 2. Colorado sand/gravel and crushed stone production, 1950-1979(80). Data from U.S. Bureau of Mines Mineral Yearbooks and Annual Advance Summaries.

control. Sand and gravel thus prove to be very prominent and vital in our life style.

Sand and gravel of Quaternary or latest geologic age (see geologic time scale in Appendix) occur as alluvium or unconsolidated sediments along most rivers and streams in the Colorado Piedmont, on the West Slope, and in larger mountain valleys. These sources may be classified as flood-plain, terrace, valley fill, alluvial fan, and pediment (upland). The Ogallala Formation (late Tertiary age) contains semiconsolidated sand, gravel and conglomerate and is a common source of material on the state's eastern plains. Thick valley-fill sediments in the Alamosa Formation provide an ample source of alluvial aggregates in the San Luis Valley. In the higher mountain valleys, parks, and intermontane basins of central Colorado, Ice Age glaciers formed till and moraines from which outwash deposits provide an adequate supply of somewhat cleaner and better sorted material.

Fine sand aggregate found in the extensive dune fields of eastern Colorado resulted from thousands of years of the wind's winnowing action on the major valley-fill sediments. Sand on the West Slope is found in much smaller eolian areas and in valley-fill and alluvial fan deposits along streams that head in terranes composed of sedimentary rocks.

A variety of other materials can be used for different kinds of construction jobs. Most often these materials are used when no other sources of gravel are available or where job specifications are not demanding. In some cases their use may even be preferred over sand and gravel. Conglomerate is simply a gravel that has been indurated by the cementing action of silica, clay, or carbonate interspersed among the grains and clasts. Usable conglomerates in Colorado vary greatly in geologic age and degree of cementation--from the Vallecito metaconglomerate (Precambrian) in La Plata County (Plate 8), to the quartz- and chert-pebble conglomerate of the basal Dakota Formation (Early Cretaceous) near Dinosaur (Plate 1), to loosely cemented conglomeratic sands of the Dawson Formation (Paleocene) in Douglas and Elbert Counties, to the Ogallala of eastern Colorado, and to some respectably cemented Quaternary upland gravels in Mesa County and elsewhere.

Granite and related igneous rocks physically disintegrate by frost action and the weathering of micas into a sand-sized granular material called grüs, which is found in most mountainous terrains where Precambrian rocks have been exposed. Grüs is well suited for mountain road construction and maintenance, but most often it is the only available source of material. Most of these operations (designated "gtu") are found in Teller, Park, Douglas, Jefferson, and Larimer Counties (Plate 9, 10, 11).

Many of Colorado's early mining camps built smelters to recover base and precious metals from mill concentrates. Fluxes, combined with gangue minerals and other impurities in the melt, were drawn off to solidify as slag. Historically a waste material, slag has now achieved notoriety as a useful construction material. The largest slag processing operation is found on the dump at CF&I's steel mill in Pueblo (Plate 11), where the slag is crushed and graded for railroad ballast, aggregate, and road metal. Other operations were noted at Canon City and Leadville (Plates 6, 11).

Many heterogeneous materials (soil, talus, colluvium, weathered rock, rubble, and "borrow") find local intermittent use from the repair of washouts to major embankments for highways and reservoirs. Only the larger of these operations have been plotted.

Industrial and specialty sands make up the remaining 3 percent of all sand and gravel production. Silica sands for glass manufacture, molding and foundry use, and oil-well hydrafracturing must meet very tight chemical and physical specifications. Hydrafrac sands currently are produced from eolian deposits north of Colorado Springs (Plate 11), and a new operation in the Sawatch Quartzite (Cambrian) has been approved west of Larkspur in Douglas County (Plate 10). Specialty and construction sands come from alluvial deposits along Cherry Creek and Sand Creek in the Denver area. Molding and other silica sands formerly came from Dakota Group sandstone quarries in Jefferson, Douglas, Pueblo, and Fremont Counties (Plates 11, 17). Current production in Boulder and Larimer Counties supplies silica for cement manufacture and glass sand for the state's only container-glass plant in Wheat Ridge.

Of all the nonmetallics, sand and gravel most readily show the interdependence of nearness of market, transportation routes, and materials sites. Gravel like any other mineral, of course, must be mined where it has been deposited by Nature; therefore, one sees pit locations concentrated along major streams and rivers. In populated areas sites must be located as close as possible to the point of the material's end use to minimize the burden of transporation costs. Gravel, stone, and other rock products intrinsically are low unit-value materials, and a significant part of the price paid by consumers originates from transporting the raw material from pit to plant and from plant to jobsite. Present and projected FOB prices and ton-mile transportation charges suggest that the consumer's price for a truckload of gravel soon could double if the load must be trucked more than 30 miles. Rising fuel costs could readily lessen that distance. "Distance to market" is the primary criterion the gravel industry uses in selecting, evaluating, and developing new production sites, and although simple in concept, it is often ignored or misunderstood in local decisions affecting mineral conservation and competing land uses.

Crushed Rock

This category of nonmetallics includes the greatest variety of natural materials--sedimentary, igneous, and metamorphic rocks--and encompasses the greatest number of end uses. Like sand and gravel, crushed rock finds its principal use in construction, namely for aggregate, road material, and cement manufacture. Production in Colorado recently peaked at 6,562,000 tons (valued at $14.8 million) in 1974 and has followed a trend generally similar to sand and gravel (Figure 2). Limestone accounts for 65 to 75 percent of total crushed rock production. The divergence between the total stone curve and that for limestone in recent years indicates increasing production of nonlimestone crushed rock for aggregate, probably attributable to the Denver metro area. The rise in the limestone curve can be attributed to increased capacity at Colorado's three cement manufacturing plants and perhaps some increase in crushed limestone for aggregate. As gravel supplies diminish in the more populous areas, crushed rock undoubtedly will supply a larger percentage of the state's aggregate needs.

Most crushed rock used for aggregate comes from the Precambrian igneous-metamorphic complexes and Tertiary igneous bodies that make up the cores of the principal mountain ranges. Extrusive (volcanic) igneous rocks have been quarried mainly on the West Slope, in the south-central volcanic fields, and to some extent on the East Slope.

The manufacture of portland cement requires the kiln firing of a proportioned mixture of limestone, calcareous shale (marl), and silica. The limestone and marl quarried at the plant sites come from the Niobrara Formation (Late Cretaceous), which yields a remarkably suitable mixture of the lime and shale requirements. The Fort Hays Limestone (lower) and Smoky Hill Shale (upper) Members of the Niobrara crop out in the hogback belt along most of the Front Range and in the Canaon City Embayment and then structurally flatten into southeastern Colorado where they crop out over many square miles.

Versatile Colorado limestone finds important use as fluxing agents in steel manufacture and ore smelting. Limestone for these uses probably was the first major application of crushed stone and limestone in the state. In the 1870s and possibly sooner, Arkansas River Valley deposits supplied fluxstone to the early Pueblo steel plants and to the smelters in Pueblo, Canon City, Leadville, Salida, and other cities. For its Pueblo mill, CF&I Steel Corporation quarries high-calcium Leadville Limestone (Mississippian) at Monarch Pass and Fremont Dolomite (Ordovician) west of Canon City (Plates 7, 11). Due to diminishing reserves at the Monarch site, the company has proposed a large, modern quarry in the Leadville Limestone on the eastern flank of the White River Uplift in Garfield County.

In similar fashion, high-calcium limestone removes impurities from raw and processed liquors in the sugar-beet refining process. Leadville Limestone quarries in Fremont, El Paso, and Chaffee Counties formerly produced this "sugar rock", but the only quarry currently producing such stone is located in the Ingleside Formation (Pennsylvanian) north of Fort Collins (Plate 9). This rock is railed to Nebraska, and the stone for Colorado sugar plants comes from an equivalent unit in southern Wyoming.

High-calcium limestone is in demand as a scrubbing agent for sulfurous flue-gas emissions at coal-fired power plants in Colorado, Wyoming, Utah, Arizona, and New Mexico. Some stone already is trucked from the Monarch Pass quarry to a power plant in Craig in Moffat County. The Leadville and possibly other limestones can satisfy much of this important demand if a large enough and chemically acceptable reserve can be located and developed near rail facilities. The most likely areas for future quarry sites are the San Juan Mountains and the White River Plateau where the Leadville crops out and has been quarried already. Less information is known about the Leadville's equivalent carbonate unit, the Madison, in the Uinta Mountains area of western Moffat County.

Colorado gypsum finds its main uses as a cement retarder, fertilizer and soil conditioner, and raw material for the manufacture of wallboard and tile. Jefferson and Douglas Counties reported the earliest mining of gypsum in Colorado from beds in either the upper Lykins Formation (Permian-Triassic) or Ralston Creek Formation (Jurassic) (Plates 9, 17). Perry Park Stucco and Land Plaster Company operated the Douglas County site from 1898 to 1901. Other early sites include 1) town of Gypsum, Eagle County (1906-07), 2) Roaring Forks Plaster Company quarry and mill site (1907-11) now under Ruedi Reservoir (Plate 6), and 3) Garden of the Gods, Colorado Springs (1900-07). A U.S. Gypsum Company quarry and plaster mill (now abandoned) operated for many years on the nose of the Big Thompson Anticline west of Loveland (Plate 17). Minor production has been reported from the a) Wanakah Formation (Jurassic) near Black Canyon of the Gunnison (Plate 7), b) Moenkopi Formation (Triassic) in southern Mesa County (Plate 3), and c) Ralston Creek Formation at several unverified sites in eastern Las Animas County (Plate 16).

Current gypsum production centers in Larimer and Fremont Counties. Three quarries operate a low-dipping gypsum bed in the Lykins Formation near Table Mountain in Larimer County (Plate 9). Gypsum for plaster and cement from either the Lykins or Ralston Creek Formations was mined in the 1930s and 1940s from several small quarries at the southern end of the Front Range in northeastern Fremont County (Plate 11). Mining in the third district, at Coaldale in southwestern Fremont County, began in 1903 when Colorado Portland Cement Company opened the first quarry to supply its plant at Portland. The ore comes from the Swissvale Gypsum Member of the Minturn Formation

(Pennsylvanian). The Flintkote Company, who now operates the site, transports the raw ore by rail about 50 miles down the Arkansas River to its wallboard plant at Florence.

Production statistics for crude gypsum are not available through 1954 and for 1957 because the U.S. Bureau of Mines combined Colorado's output with that of other states (Figure 3). Annual production from 1955 to 1970 fluctuated around 100,000 tons, but the 1970s saw a dramatic increase in response to higher demands for construction materials (wallboard and cement). Since 1972 Colorado has annually contributed less than 2 percent of the nation's total crude gypsum production, its highest percentage (1.9) coming in 1979, its most productive year, when the state mined 275,000 tons of crude gypsum valued at $1.7 million.

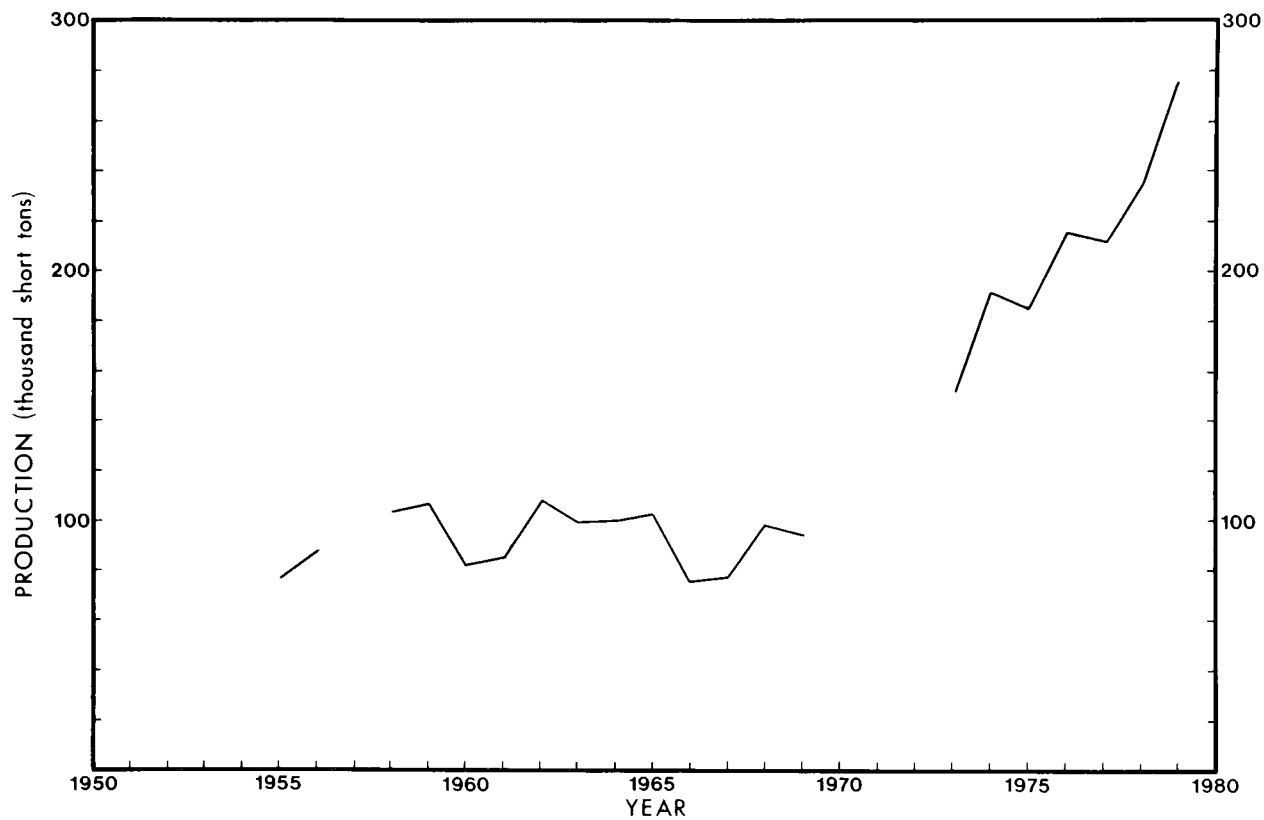

FIGURE 3. Colorado crude gypsum production, 1950-1979. Data from U.S. Bureau of Mines Mineral Yearbooks and Annual Advance Summaries. Figures for 1950-1954 and 1957 were combined with those of other states; 1970-1972 figures withheld to avoid disclosing company confidential information.

Unusual materials of Tertiary and Quaternary age come from three of Colorado's youngest volcanic deposits. Screened aggregate and road material are mined from a cinder cone that gave rise to a 640,000-year-old basalt flow along Rock Creek northeast of McCoy in Routt County (Plate 6). On a low-profile cone 2 miles west of Mesita in Costilla County (Plate 12) Colorado Aggregates Company produces lightweight reddish-brown and black scoria for roofing and decorative stone, hydroponic ballast, and gas-barbecue briquettes. Much of the red scoria comes from San Antonio Mountain northwest of Antonito at a quarry in older basalt flows of the Hinsdale Formation (Miocene-Pliocene) (Plate 8). Dotsero Block Company operates the last quarry at a small volcanic vent known as Dotsero Crater, located 1.5 miles northeast of the town of Dotsero (Plate 6). The basaltic lava that flowed from this vent has been dated at 4,150 years, the youngest known volcanic rock in Colorado.

Volcanic ash is found in the central and southwestern Tertiary volcanic fields and intermixed with Tertiary and Quaternary sedimentary rocks along the Front Range and on the eastern plains. Very small-scale ash operations began about 1895 at several deposits of probable Quaternary age around Durango (Plate 8), but not all could not be pinpointed from the old literature accounts. An ash bed in the Ogallala Formation at Wray in Yuma County (Plate 13) was worked many years ago, but the only recent interest there was a proposal by a Kansas firm to use the ash as a filler in asphalt paving mix. This bed or another in the Ogallala also was worked north of Akron and at Reiradon Hill east of Sterling (Plate 13). An exact location could not be found for an ash that occurs 5 miles east of Kremmling in Grand County (Plate 5) and that reportedly was used in the manufacture of hand soap and scouring powder. The deposit probably lies in the upper Troublesome Formation, composed of Miocene siltstone, sandstone, and conglomerate.

Perlite is an industrial term for any volcanic glass that, because of its contained water, will suddenly expand or "pop" when heated to temperatures of 1800° to 2000°F. Geologists restrict the term to one such variety of glass that exhibits an unusual spherulitic "onionskin" texture. America's perlite industry began in New Mexico and only as late as the 1940s. About the same time, exploration in Colorado revealed commercial perlite in a rhyolite flow at Rosita, which is the site of the state's only current production (Plate 11).

The Persolite Company trucks the crude ore to its expansion plant in Florence. A small amount of perlite came from a steeply dipping flow at Ruby Mountain near Nathrop in Chaffee County (Plate 7). As perlites are known to result from the alteration and hydration of obsidian, the black volcanic glass, many of the Nathrop spherules contain cores of unaltered obsidian, commonly known to mineral collectors as "Apache tears". Perlite at Bald Mountain volcano, the source of the Nathrop volcanics, is now under investigation for its commercial possibilities. A fourth deposit known as Polvo Blanco, reportedly is a fine-grained wind-reworked perlite mined in the late 1940s somewhere near Gardner (Huerfano County), but the site could not be located.

Although all crude perlite ore comes from seven western states, 79 perlite expansion plants operate in 33 states. Colorado's second expansion plant, operated by Grefco, Inc., at Antonito, receives its crude ore by truck from mines in the No Agua Mountain district in Taos County, New Mexico. Silbrico Corp. and Johns-Manville Corp. also truck ore from this district to their respective rail-loading facilities also at Antonito. Exact production figures are not available, but in 1977 Colorado ranked fifth in crude ore output and eighth in expanded perlite production, moving up to sixth position in 1979.

Dimension/Monumental Stone

Some rocks that meet the physical and aesthetic requirements for color, grain size, texture, uniformity, and resistance to weathering can be cut and finished for building stone, veneer, flagstone, curbing, walkways and paving stone, hearthstone, monuments and memorials. Igneous, sedimentary, and metamorphic rock in Colorado all have been quarried for these uses, but activity has substantially waned through the years, as apparent on the production graph in Figure 4. The 1956 peak of 123,443 tons, 99 percent of which was attributed to sandstone, ranked Colorado second in the country in dimension sandstone production. However, the use of flagstone and stone for other major building applications has lost popularity since the 1950s partly because of increased quarrying and finishing costs and because of the availability of cheaper alternate building materials, at least in this region. Colorado's present dimension stone activity is limited to two or three monumental granite quarries in Larimer and Teller Counties and intermittent

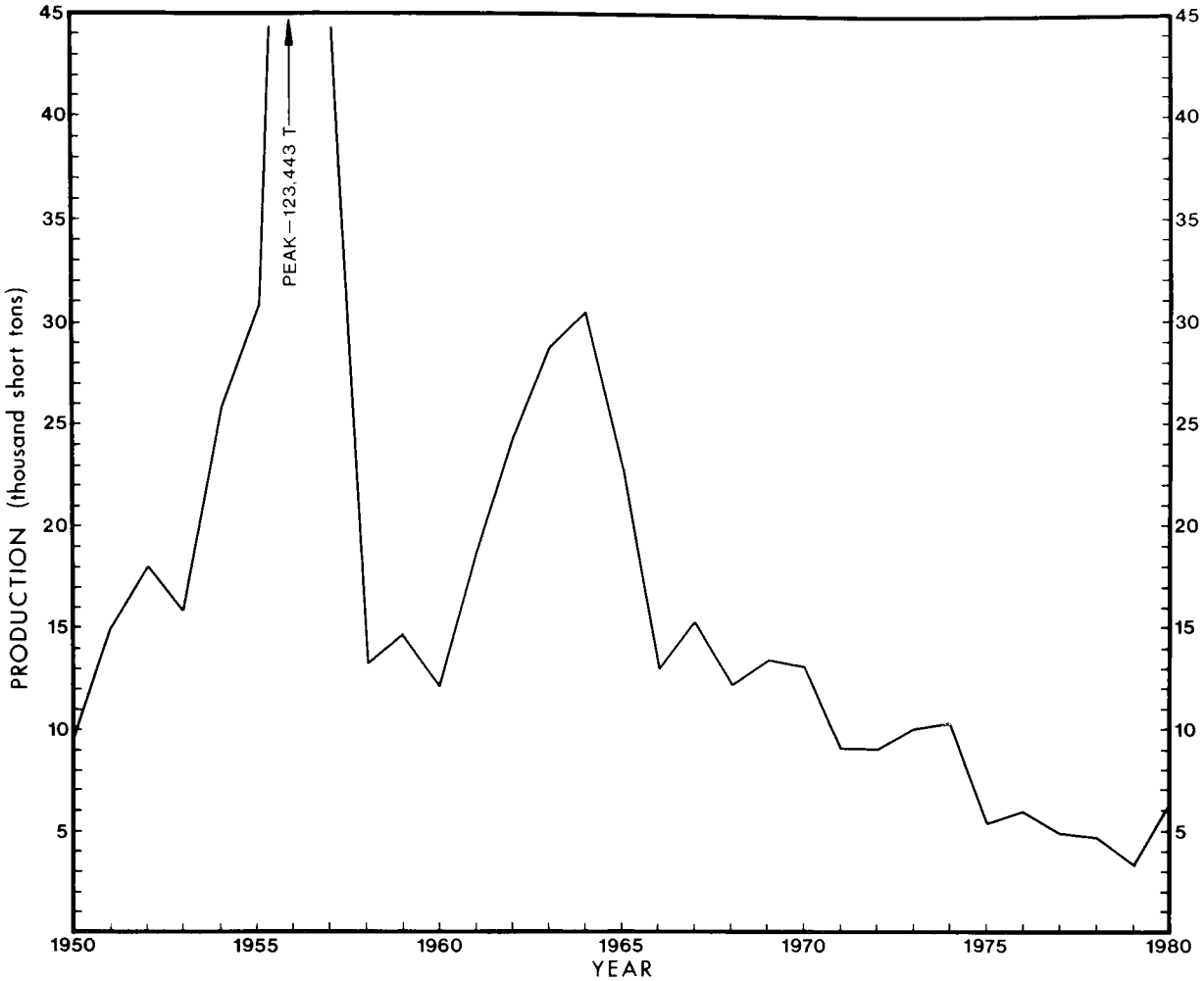

FIGURE 4. Colorado dimension stone production, 1950-1980. Data from U.S. Bureau of Mines Mineral Yearbooks and Annual Advance Summaries.

working of several flagstone (sandstone) quarries along the northern Front Range. Since 1970, output has dropped below that of 1950, reaching a low of 3,295 tons in 1979.

Most of the igneous rocks quarried for dimension stone are found in the Precambrian crystalline cores of the major mountain ranges. Front Range sources include the Pikes Peak granite in Teller County and the Silver Plume granite or quartz monzonite in Clear Creek, Jefferson, and Boulder Counties (Plates 9, 10). Quartz monzonite and granodiorite often resemble granite in color and texture and in the trade can be mistaken for it, as evident in the Cotopaxi and Texas Creek quarry districts of southwestern Fremont County (Plate 11). One exception in terms of age is the Whitehorn Granodiorite (Cretaceous) that intrudes Paleozoic sedimentary rocks east and northeast of Salida in the

Turret and Cameron Mountain districts. Perhaps the most noted of the granitic rocks is the Aberdeen gray granite that was quarried 7 miles southwest of Gunnison (Plate 7) in the 1890s for the exterior of the State Capitol in Denver.

The Castle Rock area of Douglas County (Plate 10) supplied the region with a light, pastel, volcanic rock known as rhyolite as early as the 1870s and may well have been the site of Colorado's first dimension stone activity. This rhyolite ash flow (Wall Mountain Tuff) was erupted during early Oligocene time from now extinct volcanoes in south-central Colorado and is preserved as mesas and small buttes.

Rough, unfinished cobbles and boulders of Paleocene latite lava from the Table Mountain flows at Golden (Plate 7), although not quarried, were used locally as building stone. A quartz latite in the Fish Canyon Tuff (Oligocene) provided local building stone at two sites southeast of Del Norte in Rio Grande County (Plate 8).

Sandstones dominate the sedimentary building stones, the most noted of which is the Lyons Sandstone (Permian) along the central and northern Front Range in Jefferson, Boulder, and Larimer Counties. The state's flagstone industry began in the 1880s at the town of Lyons where the east-dipping hogback of this red, eolian sandstone provided easy access and ample quantities of minable stone. The trace of the beds on Plate 17 is conspicuously marked by the concentration of quarries, whose patterns reflect occasional duplication, offset and bending of the section by folding and faulting.

A second old sandstone district , the Sand Hill, also dating from the late 1800s, lies along Colorado 76 southwest of Pueblo (Plate 17) on the Columbia Heights Anticline, which has upfolded the Codell Sandstone Member of the Carlile Shale (Late Cretaceous). Other flagstone and dimension stone quarry sites include 1) Harding Sandstone(?) (Ordovician) or "Manitou Green Stone" at Manitou Springs, El Paso County, 2) Kayenta Formation (Triassic) at Loma and Colorado National Monument, Mesa County, 3) State Bridge Formation (Triassic) on the Fryingpan River east of Basalt, Eagle County, and 4) Dakota Sandstone (?) 1.5 miles west of Gunnison.

Old reports cited the local use of sandstone on the plains of Larimer, Boulder, and Weld Counties, but no specific sites could be found. The stone might have been Fox Hills Sandstone or a prominent marine sandstone in the Pierre Shale, both of Late Cretaceous age.

Travertine, a spring-deposited limestone, has been quarried from three sites in the Arkansas River valley in Fremont County: 1) northwest of Canon City, 2) north of Cotopaxi, and 3) at Wellsville. The Quaternary-age stone has found both exterior and interior use in buildings in Denver, Boston, Washington D.C., and elsewhere. Crushed travertine chips have been marketed for use as terrazzo, fluxstone, and sugar rock.

The only known conglomerate used for dimension stone is the Fountain Formation (Permian-Pennsylvanian) at a quarry along U.S. 50 northwest of Canon City (Plate 11).

As their name implies, metamorphic rocks have undergone changes in composition and texture from their original state, which may have been any other rock type. Colorado marble, the predominant metamorphic dimension stone, resulted from the recrystallization of limestone, mostly of early to middle Paleozoic age (Ordovician to Mississippian). Heat and pressure caused the transformation during the sediments' deep burial and subsequent uplift and structural deformation around the mountain ranges where they are now found. Marble quarries in recrystallized Leadville Limestone have operated at Canon City, Beulah (Pueblo County), Turret district (Chaffee County), and at the north end of the San Luis Valley. Unverified older reports mention marble quarrying near Aspen and southwest of Steamboat Springs. Actually the latter was reported to be "onyx marble," which may be the spring-deposited limestone or travertine deposit just south of town.

The most famous marble in the state, of course, is the Yule Marble in northern Gunnison County. Although the deposits were recognized around 1880, small-scale quarrying did not begin until 1884. The selection of Yule Marble for the interior of the State Capitol in Denver in 1895 helped spur production, but not until a railroad was built to the quarries and the town of Marble in 1906 was full-scale production realized. In 1907 work was completed on what was then the largest marble finishing mill in the world.

Following many years of mismanagement, financial troubles, fire and avalanches, and severe winter weather, rising costs and labor problems due to the Depression and war finally closed the quarries in 1940. However, Colorado Yule Marble remains one of the world's finest stones, as exemplified by its use in the State Capitol, Capital Annex, Union Station, U.S. Post Office and Customs House in Denver, in many other buildings in the eastern, midwestern and far western states, and perhaps most notably in the columns of the Lincoln Memorial in Washington, D.C., and the Tomb of the Unknown Soldier at Arlington National Cemetery.

Clay and Shale

Clay and shale, the fourth major category of construction materials, are among the state's earliest mined nonmetallic commodities. Many of the early clay mines near Golden began as underground operations, but later new mines and reactivated older mines converted to surface operations. The only underground operation believed to be active yet is in Pueblo County.

Colorado clay is used primarily for face brick manufacture and secondarily for refractory brick. As shown in Figure 5, output is directly influenced by

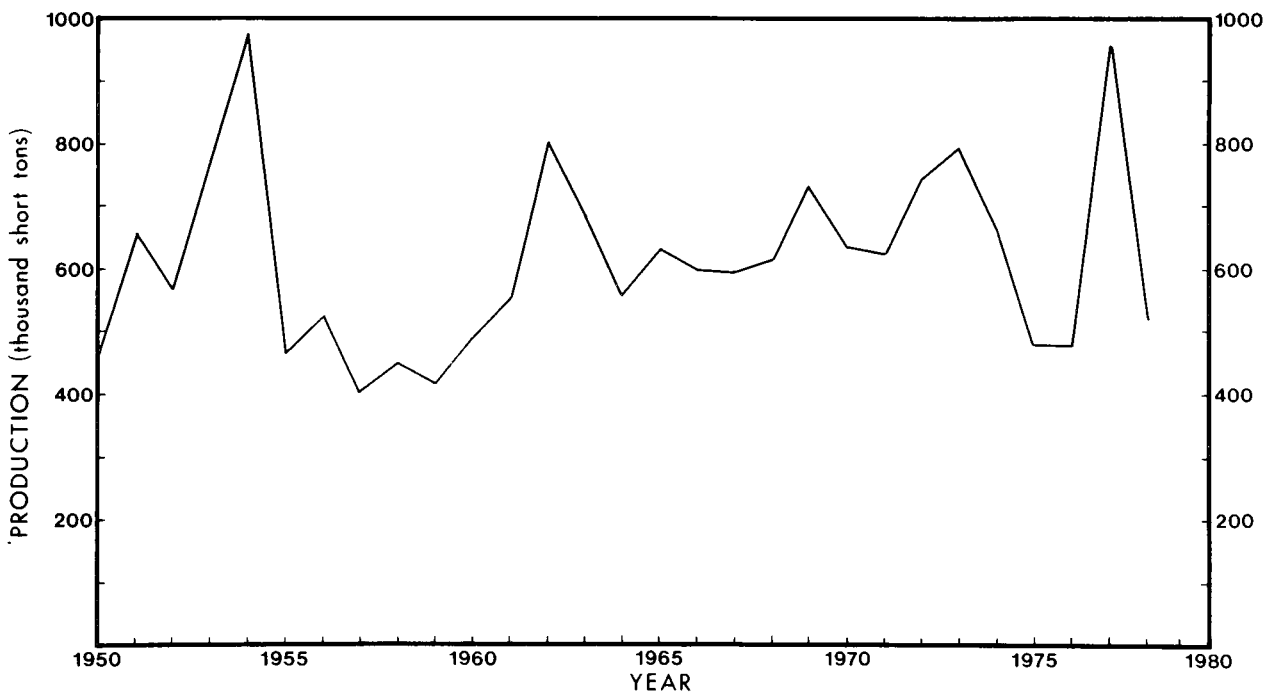

FIGURE 5. Colorado clay production, 1950-1978. Data from U.S Bureau of Mines Mineral Yearbooks.

trends in the building construction industry. A record high production for the state came in 1954 with 975,458 tons valued at $1.84 million. More recently the 1973 peak reflected a nationwide high and amounted to 793,623 tons valued at $1.7 million. Following the dramatic slump in 1974-76, production attained another peak of 960,644 tons valued at $4.7 million. Current brick clay production comes from 54 to 59 mines operating in Boulder, Douglas, El Paso, Elbert, Fremont, Jefferson, and Pueblo Counties.

Common and refractory clays have been mined to varying degrees from a number of formations, but most have come from Cretaceous and Paleocene units. Statewide, the Dakota Group (Early Cretaceous) is the only source of high-duty refractory clay, which is alumina- and silica-rich kaolinitic clay used for such high-temperature applications as kiln and furnace linings, and porcelain. The Dakota usually forms either a prominent hogback where it has been upturned along the flanks of mountain ranges or a cuesta on the plains and in other areas of low structural dip. Along the northern and central Front Range, these clays occur in the South Platte Formation of the Dakota Group and, in south-central and southeastern Colorado, in the Dry Creek Canyon Member of the Dakota Sandstone and Glencairn Shale Member of the Purgatoire Formation.

Common and low-duty refractory clays suitable for brick, tile, and pipe manufacture come from the Laramie and Benton Formations (Late Cretaceous) along the Front Range, Dawson Formation (Paleocene) in the central Denver Basin, Pierre Shale (East Slope) and equivalent Mancos Shale (West Slope) (both Late Cretaceous), and the Raton Formation (Cretaceous-Paleocene) at Trinidad. Other clays have come from units as old as Pennsylvanian and as young as Quaternary.

Bentonite is a rock type that generally forms through the chemical alteration of volcanic ash and that contains minerals that shrink and swell in response to the loss or addition of water. Bentonite finds its greatest application as a component in oil-well drilling muds, but what little has been produced in Colorado was used for canal sealing and some industrial applications, namely fillers. Bentonite or bentonitic clay horizons occur in the Morrison Formation (Jurassic), in Late Cretaceous marine shales, and in altered Tertiary-age volcanic rocks. Morrison bentonitic clay is

intermittently mined from pits south of Grand Junction in Mesa County (Plates 2, 3). An unverified citation reports bentonite mined from the Morrison in southwestern Bent County (Plate 16). Variously described as bentonite, fullers earth, or absorbent clay, a bleaching clay mined many years ago at Creede in Mineral County (Plate 8) occurs in intermixed stream and pyroclastic deposits of the Creede Formation (Oligocene) and probably resulted from the alteration of volcanic ash or zeolites. The only currently active bentonite operations are found 4 miles southeast of Howard in Fremont County (Plate 11). This material probably originated through the alteration of volcanic ash in the lower Dry Union Formation (Miocene-Pliocene).

INDUSTRIAL MINERALS

Except for fluorite and pegmatites, most of the industrial minerals found in Colorado have been produced only on a very small scale. Other not shown on these maps have been prospected but because of low grade, location, or adverse economic conditions, have never been profitably exploited. Still others are now under investigation and should very soon be in commercial production.

Barite

This mineral, a soft, dense barium sulfate ($BaSO_4$), finds use primarily as a weighting agent in oil-well drilling muds and secondarily as a filler for paper, paint, ink, and rubber, and in the manufacture of glazes, enamels, and chemicals. Most frequently barite occurs as a gangue mineral in metal mines, and a few have produced it as a by-product. Only a few other sites have yielded barite as a primary product: 1) in thorium- and galena-bearing veins in sheared Precambrian gneisses in Custer and Fremont Counties (Plate 11), 2) veins in sheared Precambrian granodiorite in Sunshine Canyon west of Boulder (Plate 9), and 3) a small vein in the Cutler Formation (Permian) south of Gateway in Mesa County (Plate 3). Long known to mineral collectors are the fine specimens of blue crystalline barite in veins and layers in the Maroon Formation (Permian-Pennsylvanian) south of Hartsel in Park County. The potential for large-scale barite production in Colorado is essentially nonexistent because Colorado lacks the thick Paleozoic black-shale sequences so

characteristic of the large, economic, bedded deposits found in Nevada, Arkansas, Missouri, and elsewhere in the world.

Bitumens

Within the extensive Tertiary sedimentary beds of northwestern Colorado and northeastern Utah, solid and semisolid hydrocarbons known as bitumens have formed by the natural fractionation of petroleum and are characterized by low specific gravity, low hydrogen content, and high carbon content. Their occurrences vary from well-defined veins of solid asphaltic bitumen to tar seeps to asphalt-impregnated sandstone in the Wasatch and Green River Formations (Eocene). Although economic bitumen production is confined to the Bonanza, Utah, district, unconfirmed small-scale production was reported on the Colorado side in Moffat, Rio Blanco, and Garfield Counties.

The bitumen variety known as gilsonite mined at Bonanza was pumped via the country's first slurry pipeline to the Gary Western (formerly American Gilsonite) refinery near Fruita (Mesa County) for processing into petroleum and asphaltic products.

The only confirmed bitumen mining in Colorado has been from a steep vein or fracture in claystone, conglomerate, and sandstone of the Middle Park Formation (Cretaceous-Paleocene) in northeastern Grand County (Plate 9). Located on Sherman Creek, a Willow Creek tributary 4 miles east of Willow Creek Pass, this small underground mine produced the variety grahamite from about 1899 to 1911. The 3,000 tons of bitumen mined reportedly was used for paint and varnish manufacture.

Corundum

As simple Al_2O_3, corundum is one of the hardest known naturally occurring substances, second only to diamond. Occurrences have been reported in Clear Creek, Fremont, Jefferson, and Routt Counties, but it has been produced only from the Turret district in southeastern Chaffee County (Plate 11). Corundum from a schist bed (probably metamorphosed Belden Shale) at the Calumet Mine was marketed as an abrasive in 1893-95. The same site also has yielded the blue gem variety, sapphire.

Fluorspar

Colorado's most economically important industrial mineral was mined continuously from 1880 through 1973 (except for 1948). The term fluorspar refers to any material containing a predominance of the mineral fluorite (CaF_2), which is used as a flux in metal smelting and steel manufacture. Its first reported production in Colorado was at Evergreen (Jefferson County), where the material supplied smelters at Black Hawk and Central City. Larger scale underground production began in 1903 at Jamestown in Boulder County (Plate 9) where fluorite occurs in breccias along the margins of Silver Plume granite and Tertiary quartz monzonite stocks. Although activity in this district ceased in 1973 with the closing of Allied Chemical's Burlington Mine, Jamestone holds the distinction of having the deepest underground fluorspar mines in the western United States. The three other major districts and their periods of activity include Wagon Wheel Gap in Mineral County, 1913-1950 (Plate 8), Browns Canyon in Chaffee County, 1927-1949 (Plate 7), and Northgate in Jackson County, 1922-1973 (Plate 5). Northgate has contributed about one-third of Colorado's total production. Long fissure veins in Precambrian granite and gneiss here were mined by surface and underground methods by Ozark-Mahoning Company (1951-1973).

During their productive era, the 1950s, Colorado's fluorspar mines annually accounted for 10 to 28 percent of the nation's total production value. Their 1972 contribution of over $4 million amounted to 31.4 percent of the nation's total. The total cumulative fluorspar production for Colorado is estimated at 1.9 million tons valued at $61 million (Brady, 1975).

Gem Stones and Mineral Specimens

Precious and semiprecious gems and innumerable mineral varieties for museum and private collections have been recovered from scores of locales across the state. Certainly not all sites could be located and shown on the maps, but a number of what appear to be the more well known localities have. Colorado is particularly noted for aquamarine (state gem stone) and other beryllium minerals at Mt. Antero in Chaffee County; turquoise from Lake,

Saguache, and Conejos Counties; amazonite from Douglas and Teller Counties; barite from Park County; lapis lazuli at Italian Mountain in Gunnison County; ruby and sapphire from the Turret district in Chaffee County; and topaz from Chaffee, Douglas, Park and Teller Counties. The reader is referred to Eckel (1961) and Pearl (1965) for descriptions of these and other sites. Those shown may be either specific gem stone or mineral collecting sites, dumps or mine sites for other commodities, or general occurrence areas. The reader is cautioned that the use of these maps and the descriptions in Eckel and Pearl (now outdated) imply nothing about the present ownership of or access to sites. Prospective rockhounds and collectors are advised to check first before attempting to vist or collect.

Graphite

As elemental carbon, graphite is most readily found as the "lead" in pencils but also finds important application in the manufacture of lubricants, paints, and crucibles. A small amount of graphite has been mined from three localities in Gunnison and Chaffee Counties. At Italian Mountain in northern Gunnison County a garnetiferous schist yielded graphite from veins that probably represent metamorphosed anthracite coal seams. During World War I two underground mines in the Tomichi district of southeastern Gunnison County produced amorphouse graphite from carbonaceous Belden Shale. At the Turret district in southeastern Chaffee County a massive graphite mined in 1909 was found interbedded with limestone, quartzite, and schist and represents a coal seam metamorphosed by the intrusion of the Whitehorn Stock.

Mica and Vermiculite

The most widely known micas, muscovite and biotite, are common rock-forming minerals, but commercial quantities are confined to pegmatites (to be discussed later). Finely ground "scrap mica", as it is called, finds important use in paints, lubricants, roofing materials, and fillers. The white mica, muscovite, was the principal product of a number of pegmatites and a coproduct of others, but the maps do not distinguish pegmatite mineralogies and products. During World War II, pegmatites in the Quartz Creek district of southeastern Gunnison County provided an important domestic source of the light metal, lithium, from a pink mica known as lepidolite.

The hydrated mica, vermiculite, displays the peculiar property of accordianlike expansion or exfoliation upon heating. Vermiculite so treated can be used as lightweight loose-fill insulation, acoustical plaster aggregate, and carriers for fertilizers and agricultural chemicals.

Because vermiculite forms by the intense alteration of biotite and phlogopite, it is usually found in mafic or iron- and magnesia-rich igneous terranes. The three major areas for occurrence and production include the Wet Mountains in Fremont and Custer Counties (Plate 11), northern Jackson County (Plate 5), and southern Gunnison County (Plate 7). Precambrian granite and gneisses host the vermiculite in the De Weese Reservoir and Sparling Ranch areas of northern Custer County. At Gem Park in far southern Fremont County vermiculite was mined along Cambrian carbonatite dikes in deeply altered gabbro and pyroxenite. Recent exploration has taken place near older vermiculite mines along the North Platte River in northernmost Jackson County, where pegmatites and granite aplites intruded Precambrian hornblende metadiorite. One large vermiculite mine operated in Cambrian or upper Precambrian pyroxenite cut by carbonatite dikes and containing pods of iron and titanium ore in the Iron Hill alkalic complex southeast of Powderhorn (Gunnison County).

As an interesting historical note, the first commercial discovery and production of vermiculite (variety jefferisite) was made in 1913 in Colorado, specifically at the Turret district in southeastern Chaffee County.

Although vermiculite exfoliation plants once operated in Colorado Springs, Canon City, and Hillside (Fremont County), the only active operation is the Zonolite Division of W. R. Grace Company, the leading domestic producer of expanded vermiculite. The company's plant in Denver processes vermiculite ore from its famous Libbey, Montana, deposits.

Mineral Pigments

Iron oxides, namely limonite, hematite, and magnetite, were noted in Colorado well before 1870, and since then have been found in more than 30 counties. Most often these mineral are mined for their iron content, thus

connoting a "metallic" mineral classification. However, in Colorado these iron oxides also have satisfied several nonmetallic applications--pigments, soil conditioners, smelter flux for nonferrous ores, and heavy aggregate. The different and unusual occurrences of these nonmetallic ores include 1) inorganic precipitation in bogs and springs, 2) concretions and nodules in shales and sandstones, 3) near-surface oxidation and replacement in limestone, and 4) gossans overlying metallic ore deposits.

Colorado iron ore was first mined in 1872 at Marshall in Boulder County. With the establishment of the steel industry in Pueblo about 1880 came larger scale production form such notable iron mines as Calumet, Star of the West, and Orient. Iron oxides for nonmetallic use were first mined in 1890 at the Delta limonite or "brown ore" deposit southeast of Delta (Plate 7). This material served as a flux for the old smelters in Salida and Gunnison. The following year several metal mines in the Leadville district produced flux for local use from manganiferous iron-silver ores.

Iron oxides specifically for pigments have come from Talca Gulch and (presumably) the Indian Paint Mines at Calhan in El Paso County (Plate 11), Paint Iron Mine in the Douglas Mountain district of Moffat County (Plate 1), and the Ferric Oxide Lode (also used for soil conditioners) near Ophir in San Miguel County (Plate 8). Lastly an iron ore contained in a gabbro at Iron Mountain (Fremont County) was used as flux and as a heavy aggregate (quarry is labelled "gb" on Plate 11). For lack of a better classification, all the operations (except Iron Mountain) producing oxides for any of the above uses have been labelled "mp".

Pegmatites

Unusual dikelike igneous bodies called pegmatites can be found in the Precambrian crystalline complexes of Colorado's major mountain ranges. Eighteen districts have been identified on the basis of geology, mineralogy, and economic value. Although composed primarily of the common rock-forming minerals--quartz, feldspar, and mica--pegmatites are more noted for their unusual and occasionally rare accessory minerals and assemblages, including precious and semiprecious gems and some mineral species having only a few known

world occurences. Pegmatites are economically important for their minable concentrations of not only feldspar and mica but also important metals--lithium, beryllium, niobium, tantalum, uranium, and rare earths. Some have yielded economic quantities of gems stones and mineral specimens.

The largest and most important districts include Crystal Mountain in Larimer County (Plate 9), Left Hand Creek in Boulder County, Clear Creek in Jefferson, Gilpin, and Clear Creek Counties (Plate 10), South Platte in Jefferson County (Plate 10), Rampart Range-Devils Head in Douglas, Teller, and El Paso Counties (Plates 10, 11), Meyers Ranch in Park County (Plate 11), Micanite in Park and Fremont Counties (Plate 11), Turret and Trout Creek in Chaffee County (Plates 7, 11), Quartz Creek and Black Canyon in Gunnison County (Plate 7).

Mica was mined as early as 1884 from Jefferson and Larimer County pegmatites, and development of others in Fremont County took place before 1900. The Quartz Creek district in Gunnison was operated during World War II solely as a source of the light metal, lithium. The peak productive era has long passed, but a few mines in Fremont County and the Rampart Range districts still produce some crushed quartz decorative stone. New interest in the rare-earth metals may bring on another productive period in the South Platte and south-central Colorado districts.

Sodium Minerals

Halite (NaCl) or common salt was a highly valued commodity during the pioneering of the Colorado Territory. As early as 1861, brines were collected from salt springs northwest of Antero Junction in southwestern Park County. By 1866 a salt works (still visible from U.S. 285) was established just southwest of Antero Reservoir and provided the staple for the entire territory. In his "Mines of Colorado," published in 1867, Ovando Hollister delightfully recounted the impressive structure:

"Nothing, we fancy, could more delight or surprise a stranger, traveling over the virginal and somewhat lonesome [South] Park, than to come suddenly upon these capacious and well built kettle-houses, drying and store-houses, saw mill, barns, dwelling-houses, &c., nestled away in one of those secluded nooks with which the Park abounds."

Thick but virtually untapped salt beds lie within the northwest-trending anticlines of the Paradox Basin in southwestern Colorado (Mesa, Montrose, and San Miguel Counties), but their remoteness and difficulty of extraction could very well prevent any significant future development. However, a brine well reportedly operated in the 1940s through the mid 1960s in the Paradox Valley of Montrose County (Plate 3). Union Carbide sent the salt and brines to Uravan to use in a salt-roast process for milling uranium-vanadium ores mined on the Colorado Plateau.

A second class of sodium minerals, collectively sodium sulfates, finds its main uses in the manufacture of kraft paper pulp, glass, and detergents. Domestic production comes from brines and dry lake beds in the far western and southwestern states. The sulfates, mirabilite and thenardite, were described in early government surveys during the 1870s and 1880s, and the earliest production (along with salt and sodium carbonate) may have come before 1900 at Soda Lakes near Morrison in Jefferson County (Plate 17). Sodium sulfate, salt, and probably sodium carbonate (trona or natron) were recovered around San Luis Lake in Alamosa County (Plate 12) in 1916 and possibly before 1910.

Colorado's most economically important sodium minerals are the sodium bicarbonate and sodium-aluminum carbonate of the Piceance Creek Basin in Garfield and Rio Blanco Counties. In addition to its rich oil shales, the basin is now considered to contain the world's largest known resource of nahcolite ($NaHCO_3$) and dawsonite ($NaAl(CO_3)(OH)_2$). The resource estimate totals 30 billion tons of nahcolite containing 19 billion tons of soda ash (Na_2CO_3) and 27 billion tons of dawsonite containing 9.5 billion tons of alumina (Al_2O_3) from which metallic aluminum can be smelted. Nahcolite will

find its principal uses as soda ash for chemical and container glass manufacture and as a scrubber to adsorb sulfur oxides from glue-gas emissions at coal-fired power plants. Another potentially exciting use for nahcolite is the production of low-cost, structurally competent, highly insulative foam-glass building material.

Several single and joint ventures in the past 15 years have attempted, unsuccessfully, to secure the necessary government permits and rights to develop these saline resources. Superior Oil Company has experimented with nahcolite for scrubber use from its site on the north side of the basin, but the only active venture now is Multi-Mineral Corporation's (subsidiary of Charter Oil Co.) development inside the U.S. Bureau of Mines' oil shale shaft on Horse Draw in the center of the basin, from which dawsonite for alumina will be recovered.

Sulfur

Sulfur finds industrial use as sulfuric acid for the chemical and process industries, phosphate fertilizer, plastics, paper products, paints, metal products, and oil refining. Colorado sulfur deposits were formed by both sedimentary and igneous processes. In Delta County, sulfur or possibly sulfur compounds from the Doty deposit near Lazear (Plate 7) was used for agricultural products and was mined from carbonaceous shales and sandstones in the Dakota. Here the sulfur may have formed through the alteration of pyrite or other reactions involving the generation of hydrogen sulfide gas (H_2S) from the contained organic matter.

The Trout Creek and Middle Fork deposits 25 miles south of Creede in Mineral County (Plate 8) apparently were worked as early as 1905. The sulfur was deposited on the surface by hot springs associated with faulting in Oligocene volcanic rocks. The Colorado-Good Hope-Vulcan deposit at the old townsite of Vulcan in southern Gunnison County (Plate 7) lies in a volcanic chimney cutting through Precambrian metavolcanics. The downward grading of sulfur into pyrite suggests deposition by the desulfurization of pyrite or by precipitation from ascending sulfurated hydrogen gases.

Zeolites

This unusual group of complex aluminosilicates of alkali and alkaline earths exhibits the properties of cation exchange and reverse dehydration, which are necessary in water and gaseous hydrocarbon purification and filtration. Although not completely understood at the time, ion-exchange capabilities were discovered in natural zeolitic soils as early as the 1840s. Since then, however, synthetic zeolites or "molecular sieves" for commercial use have held a substantial economic advantage over natural zeolites.

Colorado zeolite minerals were identified in the 1880s as vug or vesicle fillings in the latite lava flows on the Table Mountains at Golden (Plate 17), a well-known zeolite collecting area for many years. The Colorado School of Mines worked a site somewhere on the east rim of North Table Mountain in 1898 to secure specimens for its geology museum.

Of greater economic importance are the larger, more recently recognized bedded deposits in the Tertiary alkaline, saline lake beds of northwestern Colorado and other western states. Analcime occurrences have been located in the Green River Formation (Eocene), and clinoptilolite has been found in the Bridger Formation (Eocene), both in Moffat County. These zeolites are believed to have formed by the alteration of volcanic glass and ash originally deposited in saline lake environments. The only reported commercial production of zeolites in Colorado was clinoptilolite from a pumiceous ash-flow tuff in the Windy Gulch Member of the Bachelor Mountain Rhyolite (Oligocene) exposed at Creede in Mineral County (Plate 9). Larger scale zeolite development will depend on more detailed exploration (especially through the use of laboratory techniques), ease of beneficiation, and expanding markets.

POTENTIALLY PRODUCTIVE INDUSTRIAL MINERALS

Alunite

Alunite, a hydrous potassium-aluminum sulfate, is a potentially versatile mineral capable of yielding potash alum for dyeing, tanning, and paper manufacture, potassium sulfate for fertilizer, and alumina for the smelting of

metallic aluminum. Early attempts to mine and profitably refine Utah alunites largely failed because of adverse processing and marketing economics and more recently by untried technology. Most of Colorado's important deposits had been discovered by the early 1900s, and at least one (Rosita Hills in Custer County) had been more than cursorily prospected before 1900. The other notable deposits include Calico Peak near Rico (Dolores County) and Summitville (Rio Grande County). The promising deposit for future development, at least in terms of quantity and grade, lies in Red Mountain, which is located 3 miles southwest of Lake City (Hinsdale County) and is estimated to contain at least 250 million tons of potential ore. The mountain is a volcanic neck composed of quartz latite porphyry altered by hydrothermal-solfataric processes, or a late and rather feeble phase of volcanism characterized by sulfurous steam and gas emissions. Development even of this large deposit could be hampered by remoteness from rail lines, rugged topography and harsh winter weather, environmental conflicts, and lack of a regional industrial framework.

Potash

The Paradox Basin of Colorado and Utah contains 29 recognized cycles of sedimentary deposition that includes the important evaporites, salt and potash. Of the 18 potash-bearing cycles identified, 11 contain potentially recoverable potash, usually where the rocks have been upfolded near the surface. Such folds have been studied in detail in southwestern Montrose County, western San Miguel and Dolores Counties. The most abundant potash minerals occurring in the Paradox Member of the Hermosa Formation (Pennsylvanian) is this region are sylvite (KCl) and carnallite ($KCl\text{-}MgCl_2 \div 6H_2O$), and although the former has a much higher percentage of K_2O equivalent than the latter, both are suitable for fertilizer manufacture. Current potash exploitation in the basin is confined to one mine in Utah, originally an underground mine that recently converted to solution mining when it encountered structural complexities, a situation that may limit future development of the resource elsewhere in the basin.

Diamonds

Unusual volcanic vents known as diatremes along the Colorado-Wyoming border have been known to geologists for at least 15 years. These "pipes"

contain kimberlite rock, which, in the famous South African deposits, have yielded gem-quality and industrial-grade diamonds for many years. The somewhat accidental discovery of microscopic diamonds in the Colorado-Wyoming kimberlite about 5 years ago set off a flurry of geological research by Colorado State University faculty and graduate students and Wyoming Geological Survey workers as well as unfortunate problems for the landowners after the federal government published the location of the discovery. However, a great deal of information has been generated concerning the origin, geochemistry, mineralogy, and distribution of the pipes as well as some interesting field and remote-sensing exploration techniques.

The only previous development of the deposits was at the Sloan diatreme in Larimer County (Plate 9) where a small quarry once supplied crushed kimberlite for terrazzo. Cominco American, Inc., is now conducting formal evaluation in Wyoming on State of Wyoming and Rocky Mountain Energy Co. lands. The rock is tested at a pilot plant in Fort Collins (Plate 9). One or two other companies also are engaged in exploration in the area. Although industrial-grade diamond is all that likely can be produced, some gem-quality stones have reportedly been found on the Colorado side at the Shaffer pipes, which has been indicated on Plate 9 as a gem stone locality.

Readers are not advised to attempt visiting or collecting in these areas because 1) a great deal of privately owned and occupied land is involved, 2) exploration leases have been secured on much of the land, and 3) the pipes are so subtle in appearance as to be invisible to passers-by, collectors, and even trained geologists.

PROCESSING OPERATIONS

Once mined from the ground, most mineral resources require some degree of beneficiation, treatment, or mixing with other materials before they can be used. Nearly all the various plants, mills, and factories shown on these maps process or convert raw materials mined within Colorado, mostly at or very near the plant sites. A few plants, such as insulation materials and clay products, import their raw materials. The following discussions treat those major classes of operations not previously sited in the commodity discussions.

Concrete and Concrete Products

More than half of the 281 plants shown on the maps produce basic construction materials--ready-mixed concrete and concrete products. In ready-mix operations, cement and aggregate are proportioned at a central plant but are mixed (with water) and delivered by truck to the jobsite. With few exceptions, the plants shown are located in towns and cities of all sizes and usually very close to their sources of aggregate. Only a very few of these were judged in the field to be inactive.

Concrete products generally are cast forms such as block and brick, pipe, beams and panels, curbstone, vaults and septic tanks, miscellaneous and custom structural forms, and ornamental/decorative pieces.

Asphaltic Mix

A second major class of construction material product is asphaltic mix, a combination of graded aggregate, liquid or semisolid asphalt, very fine-grained filler, and occasional chemical additives that is heated, laid down and compacted over a subbase and base of coarse crushed stone to form our paved streets and highways, parking lots, driveways, and walkways. In a rapidly growing urban-suburban area, a great deal of asphaltic mix is needed not only for new construction but also for regular maintenance of existing works. As with concrete, most asphalt plants are found in or near larger towns and cities, but a few outlying plants may represent temporary sites set up for specific road construction or repair jobs.

Cement

Portland cement plants are the largest and most complex of the state's nonmetallic operations. Although Colorado is not a prominent cement supplier on the national level, its three active plants have in recent years been unable to satisfy the local and regional demands despite increases in plant capacity.

Colorado's first cement plant was built in 1899 by the Colorado Portland Cement Company at the Portland siding east of Florence in Fremont County (Plate 11). The small dry-process plant was the first of its kind to manufacture portland cement west of the Mississippi River. Under the leadership of one of Colorado's most successful businessmen, Charles Boettcher, the company became the Ideal Cement Company (now a division of Ideal Basic Industries) in 1924. Several phases of modernization since the 1920s have increased the plant's capacity to 885,000 tons/year (tpy).

A few years later, the state's second plant was built at New Castle (Garfield County), but no production was ever recorded, and the site (unlocated) was abandoned in 1905 probably because of the lack of suitable raw materials in the area. In 1908 the U.S. Portland Cement Company built a plant about one mile east of Portland, but the facility operated only until 1927. Most of the site has since been dismantled. In that same year, Ideal Cement built its second Colorado plant, the Boettcher, at Laporte, about 5 miles north of Fort Collins in Larimer County (Plate 9). Originally a 230,000-tpy dry-process plant, recent modernization has increased the capacity to 460,000 tpy. The newest cement plant in Colorado was built in 1969 at Lyons by Martin Marietta Cement Company. Recent conversion at the 430,000-tpy plant was designed to increase production, reuse process heat, and cut fuel consumption by changing to more efficient kiln technology and taking advantage of its kerogen-rich feed shale similar to the oil shale of the western slope. Approval and construction of the state's fourth cement plant are pending at the site of CF&I's old Lime quarry a few miles south of Pueblo (Plate 11).

The Niobrara Formation will continue to supply the limestone and shale needs of the operating plants as reserves are fairly substantial in those areas. The silica supplement and gypsum retarder will be obtained from other operations. Experts foresee a strong demand for cement continuing for several years in the Sun Belt and mountain states. Present and proposed construction, especially office buildings, factories, and a proposed new regional airport along the Front Range, help support this view. On the West Slope construction and development accompanying the budding oil shale industry eventually may warrant a new plant for that region, if suitable raw materials can be found.

Brick and Clay Products

This industry is well over a century old and probably began about 1865 at Golden where the early brick plants supplied materials for the mining camps around Central City and Black Hawk. During the next 50 years, the industry expanded along the Front Range, and eventually brick plants operated in most of the state's principal cities. Today only 9 plants remain in operation in Denver metro, Longmont, Pueblo, and Trinidad. Some of these active plants also manufacture clay tile and pipe. The sites of a few older dismantled plants on the West Slope and elsewhere have been plotted, too.

Colorado's porcelain industry began in 1915 in Golden. By 1924 the operation had come under control of the Coors Porcelain Company, which continues to manufacture a variety of high-specification porcelain products there and at a second plant opened in 1977 in Grand Junction.

The Idealite plant on the Jefferson-Boulder County line was, when active, the only plant in Colorado to have manufactured lightweight aggregate from expandible shale (Pierre Shale). The shale was crushed and sent through a rotary kiln at high tempterature to produce a hard, lightweight, cellular clinker that was crushed and sized for concrete aggregate in special heavy construction applications.

Insulation Materials

In addition to the expanded-vermiculite production described earlier, other insulation material manufacture in Colorado uses both natural and man-made raw materials. The Pabco Insulation Division of Fibreboard Corporation opened what is one of the world's largest calcium silicate plants in 1977 in Grand Junction. Using raw materials mined in Nevada, this 1.6-million-cu ft/yr-capacity plant manufactures insulating block, pipe covering and jacketing for high-temperature applications.

In an unusual example of processing waste utilization, Rockwool Industries of Pueblo "mines" CF&I Steel Corporation's slag pile to make its rockwool

insulation. The slag is melted in a coke-charged furnace and then forced through high-pressure steam vents that extrude masses of thin glass-like fibers. Even the waste from this operation is marketable, as the impure globular ends of the fibers are removed, graded, and sold for sandblasting "shot."

Lime

Very little remains of the small kilns that burned limestone along the Front Range for local agricultural use and mortar. The Glennon or Forelle Limestone Member of the Lykins Formation was a common source of lime for many years. The largest lime plants are found in Salida, Colorado Springs, and at several sugar refiners on the eastern plains. Nonsugar uses for lime and uncalcined ground limestone include wastewater treatment, coal-mine dusting, and poultry and cattle feed supplements.

Glass

Coors Container Company operates the only nonart/novelty glass plant in the five-state Rocky Mountain area. Its Wheat Ridge plant (Plate 17) supplies the Adolph Coors brewery in Golden. Silica sand for the plant comes from a Dakota Sandstone quarry in northeastern Larimer County.

Adobe

Adobe is a mixture of clay, sand, water, and straw that can be air- or oven-dried to form a durable, construction material. Adobe block manufacture varies from the traditional manual method of mud pit and wooden forms to a mechanized version incorporating front end loaders, pug mills, and motorized block-laying machines. Two active operations are reported in San Luis (Costilla County) and Strasburg (Arapahoe County), and others undoubtedly have produced, but no records are available to locate them. Especially in the hot, dry Southwest, adobe has become an increasingly popular and competitive building material because of 1) lower cost, 2) easy manufacture, installation, and maintenance, 3) excellent insulating properties, and 4) perhaps a subconscious desire to return to a simpler but yet attractive and functional, more native form of architecture.

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Bell System Yellow Pages

SIMPLIFIED GEOLOGIC TIME SCALE AND TERMINOLOGY

ERA	PERIOD	EPOCH	AGE IN MILLIONS OF YEARS
CENOZOIC	Quaternary	Holocene	0.01
		Pleistocene	3
	Tertiary	Pliocene	12
		Miocene	25
		Oligocene	40
		Eocene	60
		Paleocene	70
MESOZOIC	Cretaceous		135
	Jurassic		180
	Triassic		225
PALEOZOIC	Permian		270
	Pennsylvanian		300
	Mississippian		350
	Devonian		400
	Silurian		440
	Ordovician		500
	Cambrian		600
PRECAMBRIAN			

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
VERNAL, PLATE 1
1981

SCALE 1:250,000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

BASE MAP FROM ARMY MAP SERVICE

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

DRAFTED BY ETTA NORWOOD

EXPLANATION

no. of operations at location — 2 ■ ss — location and type of operation; commodity produced

- • sand, sand and gravel, rubble, borrow material
- ■ crushed rock
- ■ dimension/monumental stone (with underlined abbreviation)
- ▲ clay, claystone, shale
- ▼ pegmatite
- ◆ miscellaneous industrial minerals
- □ plant, mill
- ⊡ plant and pit
- ? questionable operation (for sand and gravel); questionable location or commodity (all others)

ABBREVIATIONS

Sedimentary Rocks:

cg	conglomerate
cl	clay, shale
clb	bentonite
do	dolomite
gy	gypsum
is	silica sand
ls	limestone
qto	orthoquartzite
ss	sandstone
tv	travertine

Metamorphic Rocks:

gn	gneiss
m	marble
qtm	metaquartzite
sc	schist

Igneous Rocks:

an	andesite
bs	basalt
cn	cinder
dc	dacite
gb	gabbro
gd	granodiorite
gt	granite
gtu	grüs
km	kimberlite
lt	latite
ltq	quartz latite
mz	monzonite
mzq	quartz monzonite
ob	obsidian
pe	perlite
ry	rhyolite
so	scoria
ty	trachyte
va	volcanic ash

Industrial Minerals/Materials:

ba	barite
Cg	graphite
co	corundum (abrasive)
fl	fluorspar
gh	grahamite (solid bitumen)
gs	gem stone/mineral specimen
ha	halite (salt)
mp	mineral pigment
mi	mica
mlv	vermiculite
Na	sodium minerals (unspecified)
S	sulfur
sg	smelter slag
ze	zeolites

Plants/Mills:

ad	adobe
as	asphalt mix
br	brick, tile, pipe
Cc	industrial diamond
cc	ready-mixed concrete
ccp	concrete products
clp	ceramic/common clay products
cm	cement
fz	fertilizer
gl	glass
gyp	gypsum products
in	insulation materials
lm	lime
xcl	expanded clay
xpe	expanded perlite

INDEX MAP

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

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GRAND JUNCTION, PLATE 2
1981

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ltq	quartz latite
mz	monzonite
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COLORADO GEOLOGICAL SURVEY
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MOAB, PLATE 3
1981

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5 0 5 10 MILES

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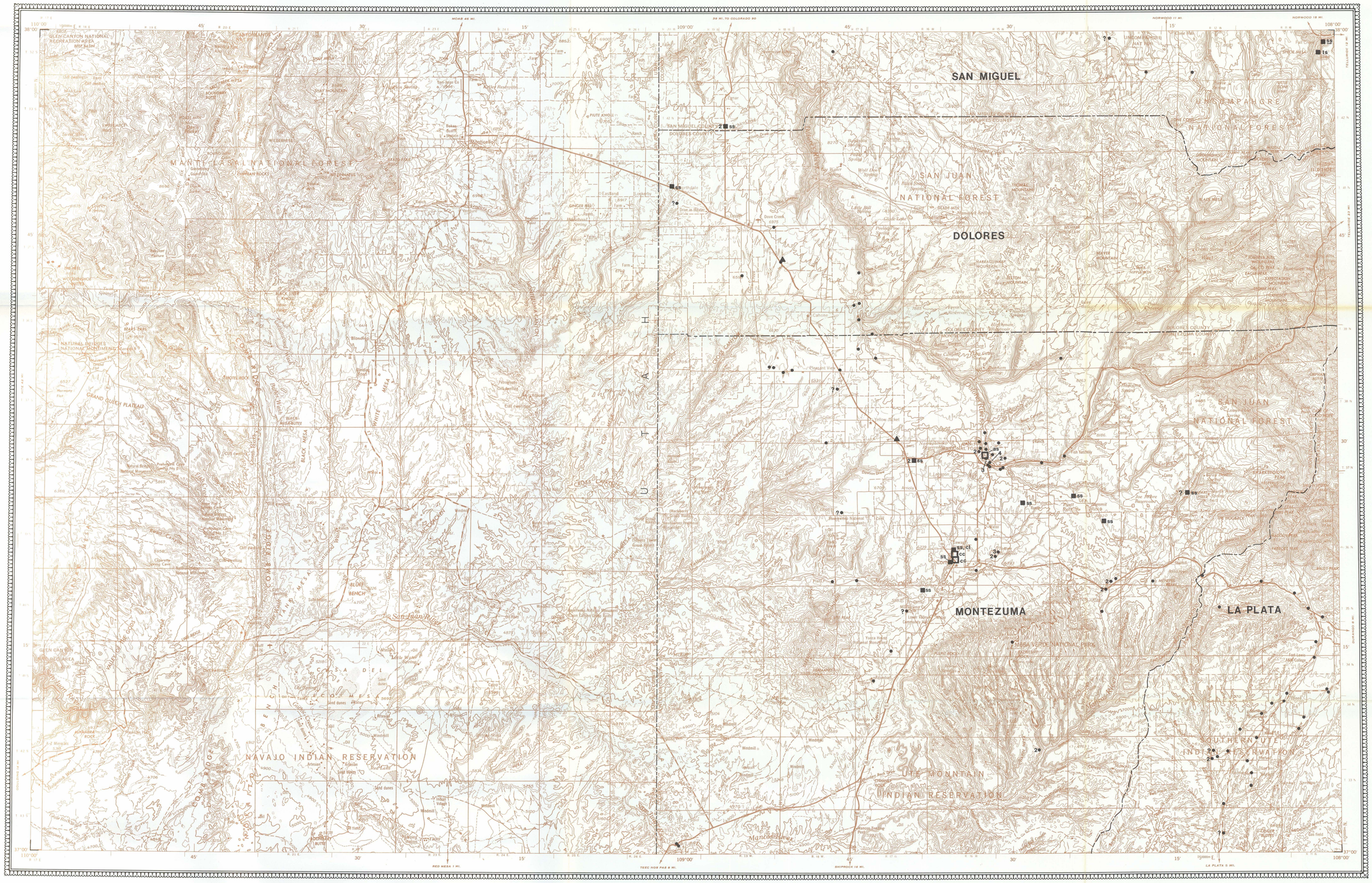
COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
CORTEZ, PLATE 4
1981


SAN MIGUEL
DOLORES
MONTEZUMA
LA PLATA
MONTROSE
MANTI-LA SAL NATIONAL FOREST
SAN JUAN NATIONAL FOREST
UNCOMPAHGRE NATIONAL FOREST
NAVAJO INDIAN RESERVATION
UTE MOUNTAIN INDIAN RESERVATION
SOUTHERN UTE INDIAN RESERVATION
MESA VERDE NATIONAL PARK
NATURAL BRIDGES NATIONAL MONUMENT
GLEN CANYON NATIONAL RECREATION AREA
UTAH
COLORADO
SAN MIGUEL COUNTY
DOLORES COUNTY
MONTEZUMA COUNTY
LA PLATA COUNTY
San Juan River
Dolores River
Mancos River
McElmo Creek
Hovenweep National Monument
Yucca House National Monument
Ruins Road
Mesa Verde Visitor Center
Cortez
Dove Creek
Egnar
Naturita
Nucla
Norwood
Telluride
Ophir
Rico
Dolores
Mancos
Towaoc
Ignacio
Bayfield
Durango
Hesperus
Mesa Verde
Redvalley
Pleasant View
Lewis
Arriola
Gateway
Bedrock
Paradox
Gypsum Valley
Disappointment Valley
Sleeping Ute Mountain
Ute Mountain
Mesa Verde
Sand Canyon
Goodman Point
Hovenweep
Cross Canyon
Ryan Gulch
Dolores Canyon
Lone Cone
Wright Mesa
Black Mesa
Blue Mesa
Cedar Mesa
Sentinel Mesa
Comb Ridge
Monument Upwarp
Abajo Peak
Abajo Mountains
Sleeping Ute Mountain
Ute Mountain
Hesperus Mountain
Mount Wilson
Lone Cone
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Engineer Mountain
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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
CRAIG, PLATE 5
1981

SCALE 1:250,000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

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DRAFTED BY ETTA NORWOOD

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INDEX MAP

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DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
LEADVILLE, PLATE 6
1981

RIO BLANCO
ROUTT
GRAND
GARFIELD
EAGLE
SUMMIT
MESA
PITKIN
LAKE
PARK
DELTA
GUNNISON
GUNNISON
CHAFFEE

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
MONTROSE, PLATE 7
1981

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- ? questionable operation (for sand and gravel); questionable location or commodity (all others)

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cl clay, shale
clb bentonite
do dolomite
gy gypsum
is silica sand
ls limestone
qto orthoquartzite
ss sandstone
tv travertine

Metamorphic Rocks:

gn gneiss
m marble
qtm metaquartzite
sc schist

Igneous Rocks:

an andesite
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dc dacite
gb gabbro
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gtu grús
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co corundum (abrasive)
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gs gem stone/mineral specimen
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miv vermiculite
Na sodium minerals (unspecified)
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Plants/Mills:

ad adobe
as asphalt mix
br brick, tile, pipe
Cc industrial diamond
cc ready-mixed concrete
ccp concrete products
clp ceramic/common clay products
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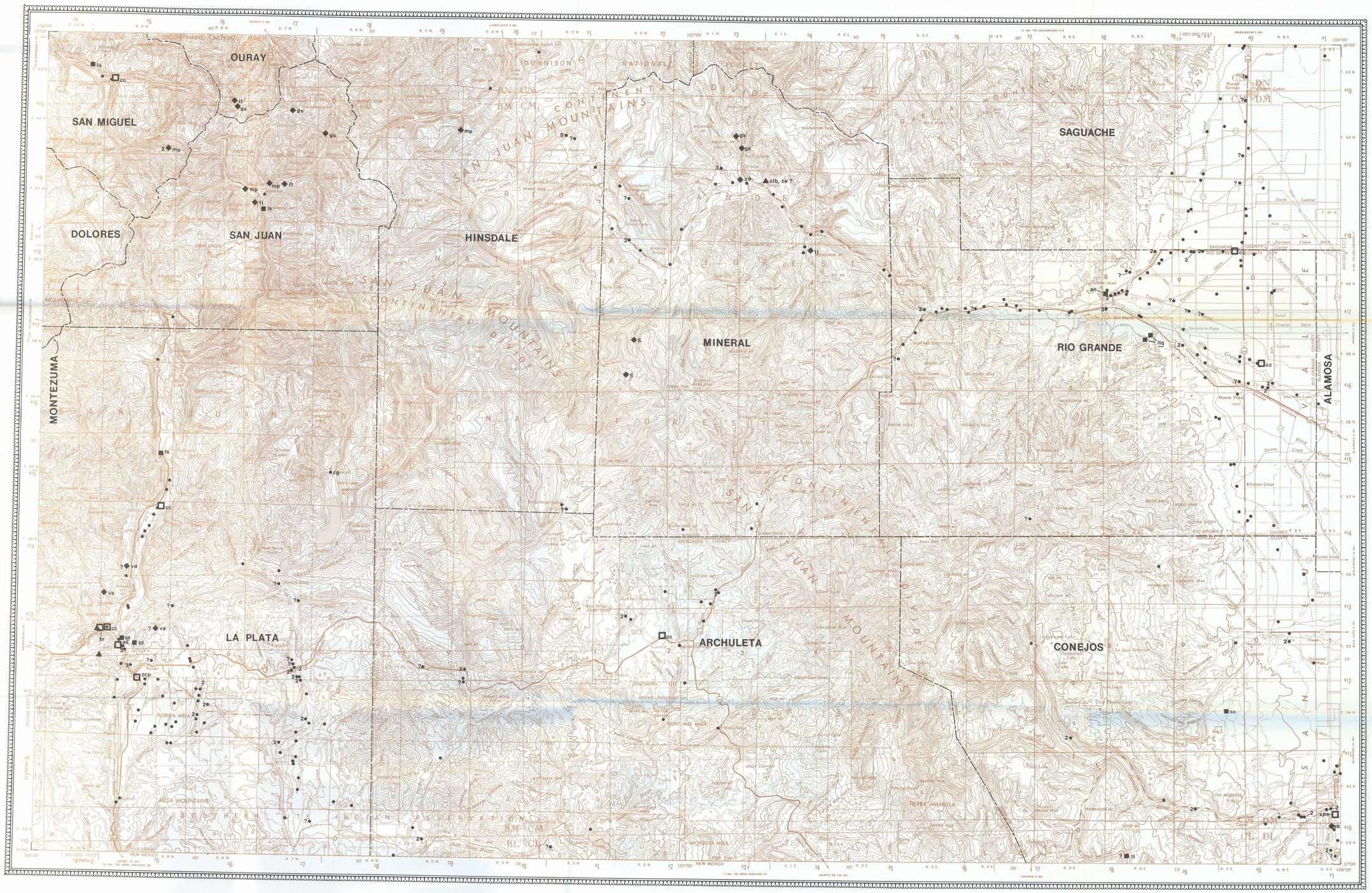
INDEX MAP

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
DURANGO, PLATE 8
1981



INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

DRAFTED BY ETTA NORWOOD

INDEX MAP

EXPLANATION

no. of operations at location — location and type of operation
2 ■ ss
commodity produced

- • sand, sand and gravel, rubble, borrow material
- ■ crushed rock
- ■ dimension/monumental stone (with underlined abbreviation)
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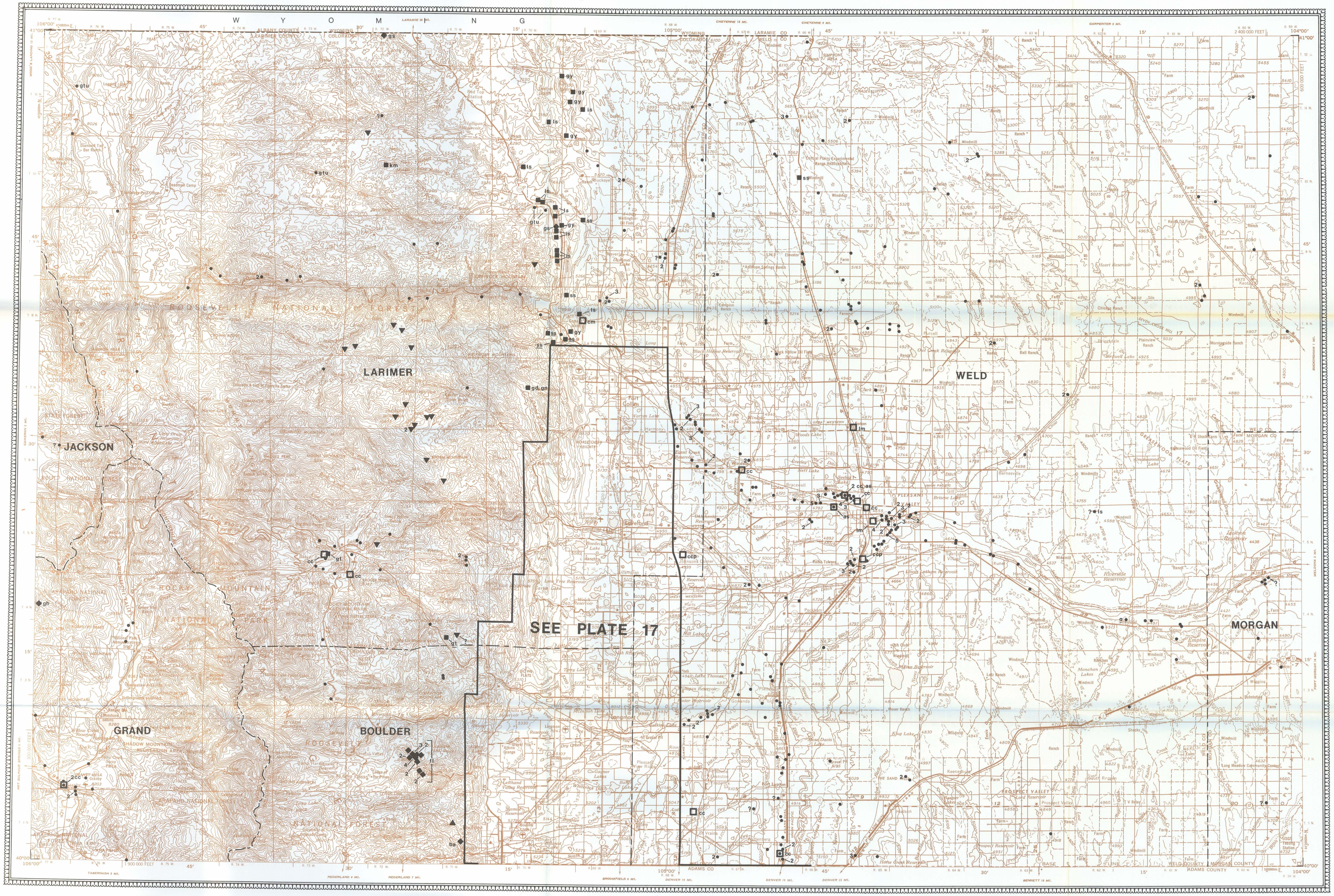
COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR



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N

SCALE 1:250,000
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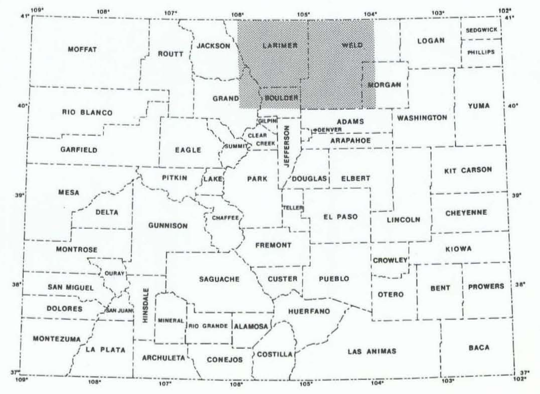
5 0 5 10 KILOMETERS

BASE MAP FROM ARMY MAP SERVICE



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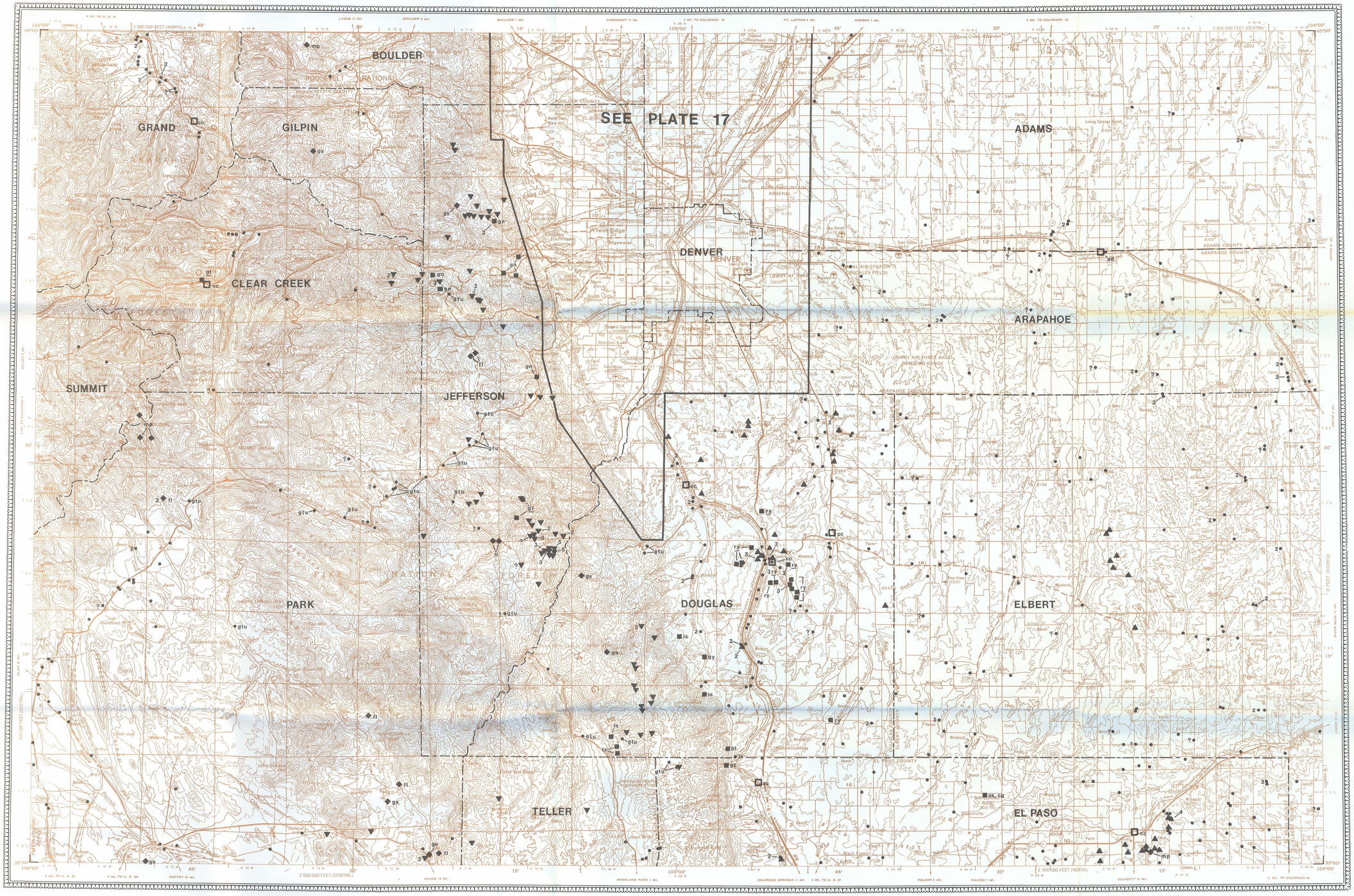
INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

DRAFTED BY ETTA NORWOOD

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
DENVER, PLATE 10
1981



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BY STEPHEN D. SCHWOCHOW

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
PUEBLO, PLATE 11
1981

SCALE 1:250,000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

BASE MAP FROM ARMY MAP SERVICE

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

DRAFTED BY ETTA NORWOOD

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
TRINIDAD, PLATE 12
1981

SCALE 1:250,000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

BASE MAP FROM ARMY MAP SERVICE

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

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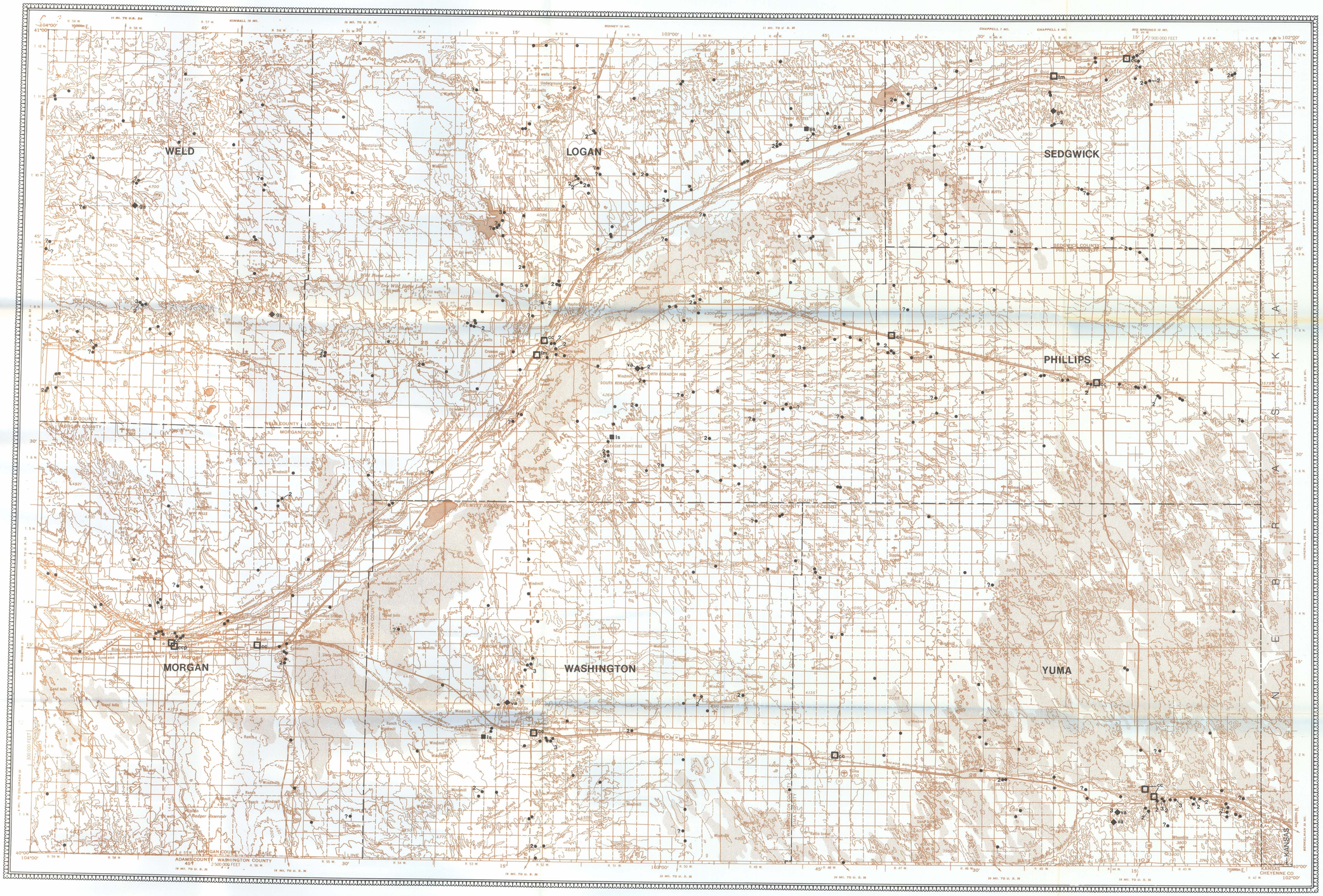
xpe	expanded perlite

INDEX MAP

DRAFTED BY ETTA NORWOOD

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
STERLING, PLATE 13
1981



INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

BY STEPHEN D. SCHWOCHOW

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
LIMON, PLATE 14
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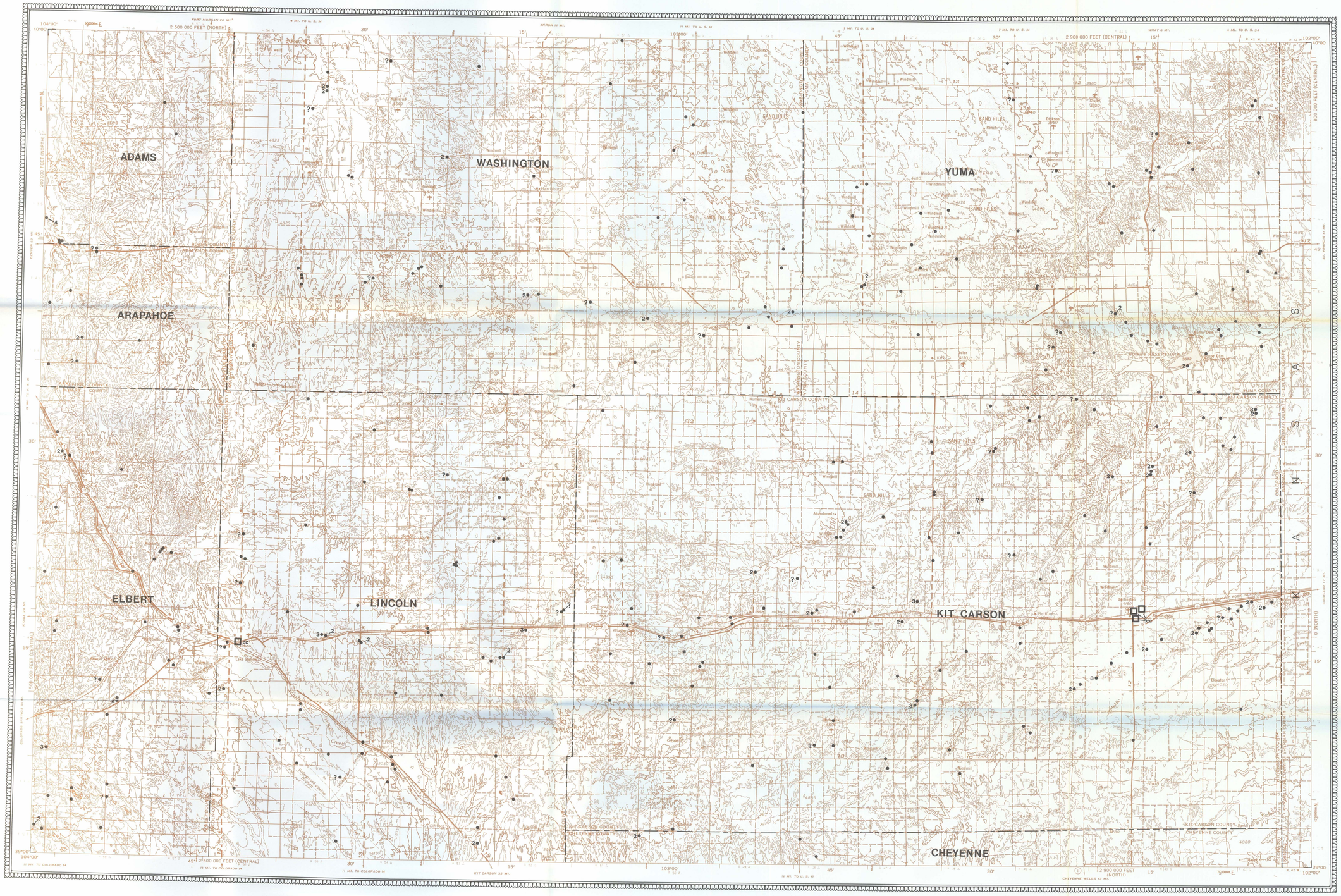

SCALE 1:250,000

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JOHN W. ROLD, DIRECTOR

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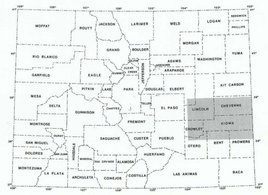
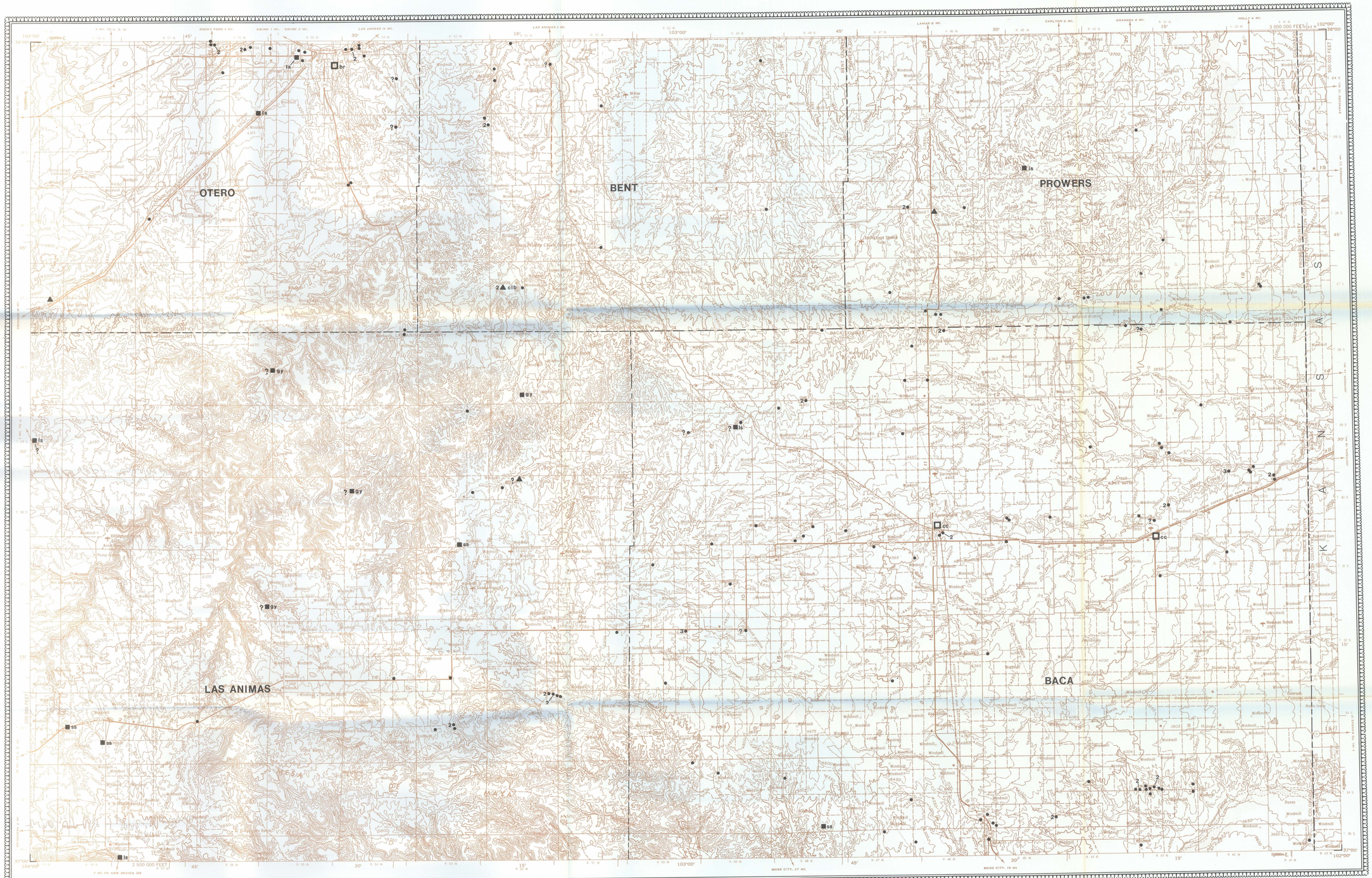


COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
LA JUNTA, PLATE 16
1981



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Cc	industrial diamond
cc	ready-mixed concrete
ccp	concrete products
clp	ceramic/common clay products
cm	cement
fz	fertilizer
gl	glass
gyp	gypsum products
in	insulation materials
lm	lime
xcl	expanded clay
xpe	expanded perlite

SCALE 1:250,000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

BASE MAP FROM ARMY MAP SERVICE

INVENTORY OF NONMETALLIC MINING AND PROCESSING OPERATIONS IN COLORADO

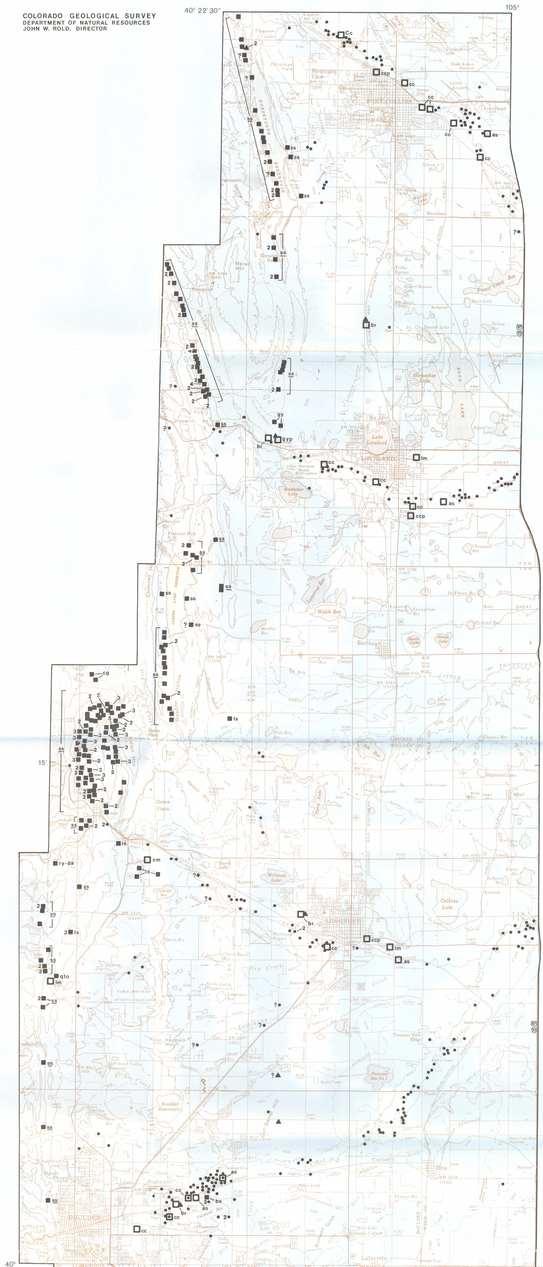
BY STEPHEN D. SCHWOCHOW

DRAFTED BY ETTA NORWOOD

INDEX MAP

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

MAP SERIES 17
PLATE 17
1981



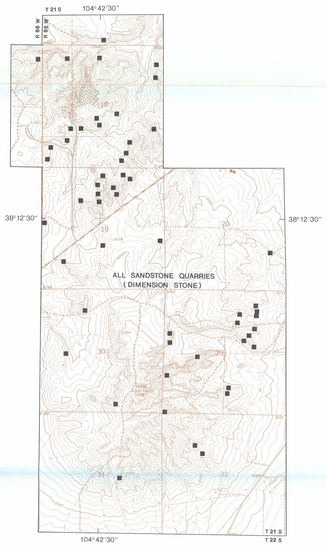
A. FRONT RANGE URBAN CORRIDOR

SCALE 1:100 000

1 ½ 0 1 2 3 4 5 MILES

1 5 0 1 2 3 4 5 KILOMETERS

BASE MAP FROM U.S. GEOLOGICAL SURVEY, 1972



B. SOUTHWEST PUEBLO

SCALE 1:24 000

1 ½ 0 1 MILE

1 5 0 1 KILOMETER

BASE MAP FROM U.S. GEOLOGICAL SURVEY, 1974

INDEX MAP

EXPLANATION

no. of operations at location — location and type of operation

2 fs — commodity produced

- sand, sand and gravel, rubble, borrow material
- crushed rock
- dimension/monumental stone (with underlined abbreviation)
- clay, claystone, shale
- pegmatite
- miscellaneous industrial minerals
- plant, mill
- plant and pit
- ? questionable operation (for sand and gravel); questionable location or commodity (all others)

ABBREVIATIONS

Sedimentary Rocks:

cg conglomerate
cl clay, shale
eb bentonite
do dolomite
gy gypsum
ls silica sand
ls limestone
qtz orthoquartzite
ss sandstone
tv travertine

Metamorphic Rocks:

gn gneiss
m marble
qtm metaquartzite
sc schist

Igneous Rocks:

an andesite
bs basalt
cn cinder
dc dacite
gb gabbro
gd granodiorite
gl granite
gtu grüs
km kimberlite
ls latite
ltq quartz latite
mz monzonite
mzq quartz monzonite
ob obsidian
pe perlite
ry rhyolite
so scoria
ty trachyte
va volcanic ash

Industrial Minerals/Materials:

ba barite
Cg graphite
co corundum (abrasive)
fl fluorspar
gh grahamite (solid bitumen)
gs gem stone/mineral specimen
ha halite (salt)
mp mineral pigment
mi mica
mlv vermiculite
Na sodium minerals (unspecified)
S sulfur
sg smelter slag
ze zeolites

Plants/Mills:

ad adobe
as asphalt mix
br brick, tile, pipe
Dc industrial diamond
cc ready-mixed concrete
cop concrete products
clp ceramic/common clay products
cm cement
fz fertilizer
gl glass
gyp gypsum products
in insulation materials
lm lime
xcl expanded clay
xpe expanded perlite

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