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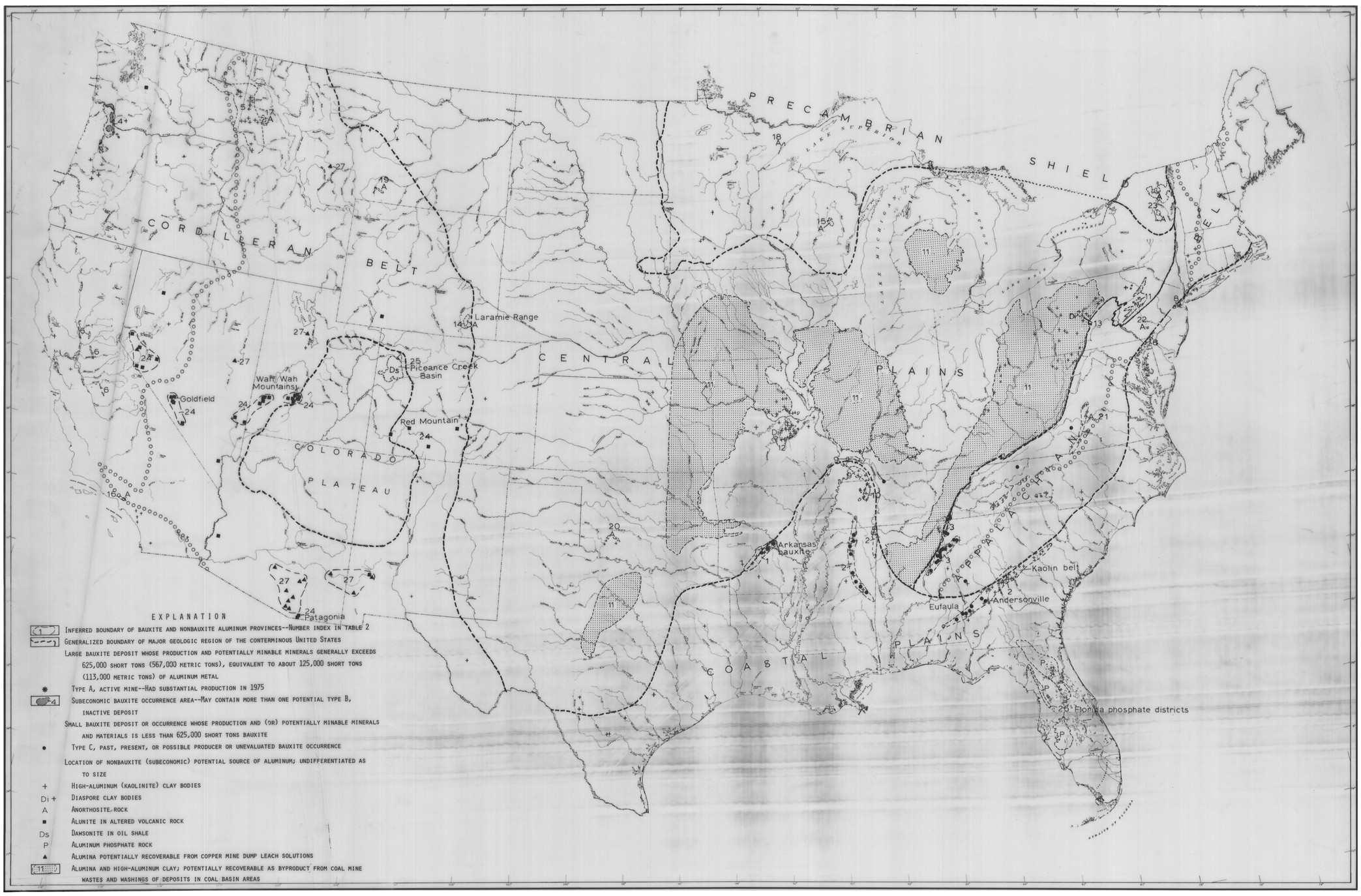
TOOKER—ALUMINUM




Planimetric Base from National Atlas 1:7 500 000, 1970

# PRELIMINARY MAP OF ALUMINUM PROVINCES IN THE CONTERMINOUS UNITED STATES

By

EDWIN W. TOOKER

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## INTRODUCTION

The map shows areas called provinces defined by groups of deposits and subeconomic occurrences of mineral materials containing potential resource concentrations of aluminum, a material that is surpassed only by iron in quantity of metal needed to sustain the industrial economy of the United States. Economic aluminum resources are available in limited areas of the nation, but there is an abundance of subeconomic but mostly unevaluated future resource possibilities in many areas. Aluminum is an abundant, silvery white, ductile, light-weight metal (specific gravity, 2.7) having efficient electrical conductivity and resistance to oxidation. The principal uses of aluminum (metal) are in the expanding construction, transportation, electrical, container and packaging, appliance, and equipment and machinery manufacturing industries.

Domestic economic deposits of bauxite, the primary mineral source, are limited and imports and secondary metal production have been increasing to meet the demand. In 1978, the gap, approximately 9 percent of the apparent consumption of nearly 5 million short tons (4.4 million metric tons) in 1978 was from reclaimed old aluminum scrap; domestic production of primary metal amounted to 4.6 million short tons (4.3 million metric tons) (U.S. Bur. Mines, 1979). Net imports of aluminum metal exceeded 600,000 short tons (545,000 metric tons) in 1978, which was a record year, but additional large tonnages of imported raw materials were also required to satisfy the remaining needs for metal and other products requiring a high-alumina content. Stamper and Kurtz (1978, p. 24) project a continued average future demand growth rate of about 3 percent annually, reaching as much as 20 million short tons (18 million metric tons) per year by 2000.

The purpose of the map is to show the location and relatively small areal extent of current domestic aluminum deposits and to emphasize the limited geologic potential (or availability) for domestic aluminum resources in the conterminous United States. The map also shows the types and location of currently subeconomic domestic substitute sources of bauxite and nonbauxite aluminum resource materials, and an accompanying table provides a preliminary estimate of the potential aluminum resource available in each province areas. Some of the substitute materials may never become economically viable (or available) where (a) the cost of energy needed to extract the metal is prohibitive, (b) they may be committed already to competing industrial needs, (c) they occur in now highly urbanized regions and their recovery is impractical, (d) their extraction will cause unacceptable environmental damage, or (e) the deposits and occurrences are too small to be considered minable now or in the future. A secondary goal of this map, therefore, is, in a preliminary way, to assess the potential availability of these materials in the future, if necessary, to satisfy needs in the conterminous United States, and not just those of current economic interest, as a guide in the development of more detailed area by area evaluation of the nation's total resource base.

The map was compiled mostly from published reports (Mark, 1963; Mosteram and others, 1960; Allen, 1929; Overstreet, 1964; Patterson, 1967; Smith and Milton, 1966; Searight and Patterson, 1967; U.S. Geol. Survey, 1962; Hall, 1978; U.S. Bur. Mines, 1976a; Cathcart and Tooker, 1979). Geologic data used to delineate some of the province areas were derived from the geologic map of the United States (King and Beikman, 1974). The rationale for province maps and some of the technical terms and geologic concepts used in the atlas of some metal and nonmetal provinces, of which this map is a part, is discussed and defined in a companion background report by Tooker (1979).

## DISTINGUISHING MAP FEATURES

### Province definition

Aluminum provinces are defined as geographic areas combining economic or subeconomic concentrations of aluminum in amounts considerably greater (except for bauxite) than the 8-percent average in the earth's crust. The aluminous raw materials within a province are generally similar in origin, mineralogy, or geologic mode of formation. For the most part, the quality and quantity of subeconomic materials have not been fully evaluated. Province boundaries are based on the location of known deposits and occurrences and, where possible, are drawn along formational boundaries of the enclosing rocks. Provinces may also include broader regions that contain favorable geologic hosts such as sedimentary coal basins, or a region containing a number of widely dispersed small porphyry copper bodies, or the boundary may be drawn arbitrarily about areas where the details of the geologic feature boundaries are not known or are complicated by containing a number of widely dispersed small porphyry copper deposits or alunite occurrences. For the most part, the latter types of provinces must be considered as more or less indefinite areas for which further systematic geologic resource assessment will be required to define or refine province boundaries.

Two main kinds of aluminum materials are considered on the map: economic and subeconomic bauxite and subeconomic nonbauxite materials. The following brief descriptions of the types of aluminous materials, whose occurrences are located on the map and resource characteristics compared in tables 1 and 2, were abstracted from more detailed information by Patterson (1967, 1977) and Patterson and Dyni (1973).

Bauxite.--Provinces that enclose economic bauxite deposits or occurrences, shown by a dot symbol, include a variety of materials that were formed in at least three geologic types of environments. Residual bauxites, such as some of those in Arkansas, contain concentrations of aluminum hydroxide minerals with iron-, silicon-, and titanium-bearing mineral impurities. These sapprolite and laterite deposits are the result of in situ tropical weathering of nepheline syenite intrusives. Aluminum was enriched at the expense of more soluble elements, which were flushed away. The alumina ($Al_2O_3$) content of metal-grade bauxites such as these is 45 to 50 percent. Lateritic type in situ weathered intra-aluminous silicate (basaltic lava flow) rocks in Washington and Oregon, shown by shaded patterns, contain subeconomic sapprolitic material whose average alumina content is about 36 percent. Sedimentary bauxite deposits represent those materials that have been transported from a (residual) source area to nearby localities, where they commonly are interbedded with other sediments. These deposits are the principal ones of the Mediterranean region and Commonwealth countries. Deposits of this type occur in Arkansas and in the southeastern kaolin belt, in Alabama and Georgia. Karst bauxite occurs in small bodies that contain unspecified mixtures of residual and washed-in sedimentary aluminous materials that are localized in sinkholes and solution cavities in a carbonate rock terrane. These comprise the main type of occurrence in the Appalachian belt.

Nonbauxite aluminous materials.--Several kinds of subeconomic aluminous-bearing materials are shown individually by symbols on the map. They comprise a distinctive group of rocks and mine wastes (table 1) that may be considered as potential sources of the metal: High-aluminum clays, mostly kaolinite, which occur in the Georgia kaolin belt, associated with bauxite deposits in Arkansas, and elsewhere; Alunite, an alteration mineral in volcanic rocks, which occurs in some areas; Aluminum phosphate rocks overlying some Florida phosphate deposits; Dawsonite, which occurs in some oil shale deposits; Anorthosite and nepheline syenite; and Coal-mine waste and washings produced from mining coal; and copper leach solutions from a number of porphyry copper mine dumps. Diaspore, which is a constituent mineral in some foreign bauxite deposits, is associated with coal bed sequences in Pennsylvania and also occurs in solution cavities in carbonate rocks in Missouri. Diaspore is unlikely to be a source of aluminum metal in the United States, but it is used for refractories and thereby reduces the nation's reliance on imported refractory-grade bauxite.

Table 1.--*Alumina content of bauxite and nonbauxite rocks and materials*

| Rock or material | Percent $Al_2O_3$ in rock or materials |
|---|---|
| Bauxite | 45 -50 |
| Aluminum phosphate rock | 5 -15 |
| Aluminous shale | 15 -307 |
| Alunite rock | 5.5-15 |
| Coal washings | 25 -307 |
| Dawsonite in oil shale | 3 |
| High aluminum-clay | 30 -35 |
| Anorthosite | 22 -30 |
| Nepheline syenite | 20 -25 |

Source: Patterson (1977)

Large deposits in the atlas maps (Tooker, 1979) have been subdivided: Type A, a large star symbol on the map, are major active mines according to U.S. Geological Survey information which have had substantial production in recent years (table 1 in Tooker, 1979); type B, a large dot symbol, are inactive (1979); type B, large dot symbol, are those temporarily inactive mines that contain additional currently subeconomic resources, former producers possibly now mined out, or those whose current production was below the level recognized in the survey, and (or) large now subeconomic but potential sources of aluminum. The only two type A bauxite deposits in the conterminous United States were in Arkansas in province 1, which was the source of more than 85 percent of the domestic bauxite. (U.S. Bur. Mines (1976b) reported 11 bauxite operations in Arkansas, Alabama, and Georgia in 1975.) No type B bauxite deposits are shown on the map; a number of inactive former bauxite producers were too small to qualify. Thus, domestic bauxite mining is limited areally as well as in the quantity produced. Underlined Lateritic ferruginous bauxite in Washington and Oregon, however, undoubtedly contains sufficient aluminum, some large occurrences, and one or more type B occurrences may be expected.

Type C, small deposits or occurrences, shown by a small dot symbol, are those not engaged in type A, and shown as small dots. Some have been mined out, or are only subeconomic occurrences that have virtually no future value as an economic source of aluminum metal, but a number of type C deposits are mined and the bauxite used in the manufacture of refractories.

It has not been possible to classify the nonbauxite deposits or occurrences (shown by individual map symbols) by size, because such information is incomplete or not available. For most, information about the quality of the potential resource is similarly unavailable. Some of the localities shown represent deposits mined for other mineral materials that also are occurrences of potential byproduct aluminum, now considered as a mine waste product. Aluminum recovery would be dependent on the mining of other commodities. Thus, nonbauxite localities are classed here as type C aluminum occurrences. When evaluated and production becomes feasible, some occurrences undoubtedly will be reclassified as type B deposits. Some of the porphyry copper mine dumps, for example, contain potentially minable aluminum more than 10,000 times the amount of the aluminum qualification for a large bauxite deposit. On the other hand, other provinces may prove to have little potential as future sources of aluminum because the resource is located in small bodies or unavailable for other reasons.

## ALUMINUM PROVINCES

The bauxite and nonbauxite aluminum provinces recognized on the map are compared in table 2, and preliminary estimates of their anticipated resource potential are made. Bauxite provinces are readily grouped by geographic regions, whereas the discussion of areally widespread nonbauxite provinces are considered by geologic types. Evaluation of bauxite is based on geologic and economic factors; the nonbauxite estimates are wholly geologic. In the following brief sections the general characteristics of the six of present and possible aluminum resources in 27 province areas are examined.

### Bauxite provinces

Central Arkansas.--Province 1, is the major aluminum producing center for the United States, and contains the largest economic potential of metallurgical bauxite. The province is located a few kilometers southwest of Little Rock, in the central part of the state. Bauxite occurs in irregular residual masses on large bodies of nepheline syenite and in ionticular omite interbedded with sedimentary rocks forming the Coastal Plain. Most of the bauxite is used for aluminum metal, but some is also mined for use in chemicals and refractories, and minor amounts were formerly produced for abrasives. Reserves are estimated to be large, but only a small part of the total resource (based on presently mined ore and sufficient to last about 20 years at the present rate of production (J. R. Patterson, oral commun., 1979). The total minable resource is approximately equal to 2 times the bauxite consumed in meeting the nation's apparent annual (1978) consumption of aluminum, on the basis of U.S. Bureau of Mines data (1979). Subeconomic resources consisting of high silica bauxite and kaolinitic clay are considerably larger than presently minable minerals, but the prospect for using such resource materials seems remote.

Alabama, Georgia, Mississippi, South Carolina, and Tennessee.--Many small bauxite deposits and occurrences are scattered through the southeastern United States in provinces 2 and 3. The principal deposits and occurrences are in sedimentary rocks underlying the Coastal Plains. Large parts of the mining areas are the Andersonville, ga., and the Eufaula, Ala., districts in province 2. Although the bauxite is still mined on a small scale for refractory product use in both of these districts. A large deposit of bauxite in province 3, near Eufaula, Ala., is estimated to contain 3 million short tons of aluminum metal. Some karst deposits occur mainly in Alabama and Georgia in the Appalachian carbonate rocks. The resource potential of these provinces is considered to be low.

Western Oregon and Washington.--Subeconomic laterite-type bauxite occurs in province 4 in the weathered parts of the Columbia River volcanics located in upland areas that are dissected by this soils and younger sedimentary beds. These occurrences are estimated to contain in the range of about a 3-year supply at the 1978 level of use, on the basis of data from Patterson (1967) and U.S. Bureau of Mines (1979). The recovery of alumina from this bauxite has been tested and proved possible. Were it not for the low-alumina content (approximately 36 percent), this material would be classed as economic rather than a subeconomic resource.

Scale 1:5,000,000

100 0 100 200 300 400 Mile

100 0 100 200 300 400 500 Kilometers

Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U.S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the Geological Survey, Branch of Distribution, 1200 Eads St., Arlington, VA 22202.

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

### Nonbauxite provinces

A number of potential sources of presently subeconomic aluminum are distributed nationwide. In most cases province boundaries may be defined by the host geologic unit in which aluminous minerals occur, but some sources occur in widely separated areally limited localities and their province boundaries are not certain or are unspecified.

High-aluminum clays.--Clay materials, mostly kaolinite, occur in variable amount and quality in province 1 associated with Arkansas bauxite, and in province 2 in the South Carolina-Georgia-Alabama kaolin belt. Clay materials also occur in variable amounts in widely separated deposits in provinces 3 and 5-10 in the Appalachian and Cordilleran belts and Central Plains. Some of the kaolinite deposits mined by Mark (1963) are not included on this map because they represent mineralogic curiosities, often in highly urbanized terranes in the east. In province 11, high-aluminum clay and alumina are potentially recoverable as a byproduct from coal mine wastes and washings of deposits containing kaolinite. This province is defined broadly to the distribution of the host coal basins, but not all areas within these approximate boundaries can be expected to contain usable material. Kaolinitic high-aluminum content, the potentially large tonnages available, and an existing extractive process make this material attractive as a future primary or byproduct source where it exists in large amounts.

Anorthosite and nepheline syenite.--These intrusive silicate rocks containing high alumina and low silica, iron, and magnesium occur locally in many parts of the conterminous United States. The rock may become an acceptable source because of the large tonnages available in provinces 14-23 and the fact that commercial processes have been developed for extracting alumina.

Alunite rock.--This material, which is used in the U.S.S.R., contains moderate to high amounts of alumina in large tonnages in Utah (areally undefined in province 24) and elsewhere in Nevada, Colorado, Wyoming, Arizona, and Washington. Alunite is associated with altered volcanic rocks in vein and replacement bodies, and as disseminations. The extraction technology is known. Potassium and sulfur are potential byproducts.

Aluminum phosphate rock.--The rock occurs as a leached zone overlying commercial phosphate deposits in Florida (province 26). The $Al_2O_3$ grade is low, but huge tonnages are possible as recovered byproduct of phosphate mining; uranium and fluorine also occur in these deposits as potentially valuable byproducts.

Dawsonite.--The mineral [3] occurs in evaporite deposits in the Cenozoic oil shales of Colorado (Piceance Creek Basin, province 25) and nonmarine sedimentary rocks in the Green River Formation in Colorado, Utah, and Wyoming, province 25, dawsonite. Its low grade, but possible large tonnages, and the relative ease to extract aluminum from dawsonite make this a potential byproduct source of the metal when the contained uranium and oil are produced.

Alumina in copper mine waste dumps.--Leach solutions from many porphyry copper deposits are known to contain alumina in amounts probably derived from the argillic alteration of plutonic rocks. If economically recoverable, porphyry copper deposits might provide a sizable future source of byproduct aluminum. A number of deposits have been shown as (unbounded) province 27, but they are scattered areally in most of the central Cordilleran belt, except where clustered in central Arizona. The aluminum potential from this source has not been evaluated.

Diaspore clay.--This clay is suitable for refractory use and occurs mainly as scattered small now depleted deposits associated with coal beds in province 11, but also in bauxite and nonbauxite in province 1, Pennsylvania. The resource potential for aluminum metal is unknown.

Many of these subeconomic nonbauxite resource materials have been studied by industry, government agencies, or universities. The Bureau of Mines (Natl. Materials Advisory Board, 1970) and the following may be considered promising potential source areas for aluminum: High-aluminum clay in provinces 1 and 2, anorthosite in the Laramie Range, Wyo., province 14; alunite in the Wah Wah Mountains, Utah, at Goldfield, Nev., Patagonia, Ariz., and Red Mountain, Colo., province 24; dawsonite in the Piceance Creek Basin, Colo., province 25; and aluminum phosphate rock in Florida, province 26. The possibilities for the recovery of alumina from coal mine wastes scattered through the Central Plains coal basins, in province 11, and from aluminous materials in copper mine waste dumps, in province 24 located in several western states, also have been investigated. Other aluminous materials not included on the map for which may be considered useful as sources of alumina, are aluminous shale, and slate, and anorthite.

Some of the geologically available potential aluminum resources may never become usable (economically available) resources even should new technology provide viable extraction methods and a highly favorable economic condition prevail. Occurrences such as those in provinces 1 and 2 contain high-grade clay materials in small amounts in restricted discontinuous lenses. Other deposits or occurrences are located in rapidly expanding urbanized regions, such as in provinces 7 and 8, or in wilderness or environmental protected areas, such as federal lands in provinces 24 and 25. Numerous isolated small deposits or occurrences may prove to be mineralogic curiosities, and some of the large low-grade masses of aluminous rock mentioned here not been fully tested and their value as aluminum resource possibilities evaluated.

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Table 2.--*Location, types of deposits, preliminary estimates of resource potential, and the status of geologic resource information of aluminum provinces*

| No. | Province: State | Province: Area | Type and mineability of Al resource[1]: Econ. | Type and mineability of Al resource[1]: Subecon. | Preliminary estimates of resource potential[2]: High | Preliminary estimates of resource potential[2]: Medium | Preliminary estimates of resource potential[2]: Low | Status of geologic resource information: Adequate | Status of geologic resource information: Insufficient |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Arkansas | Coastal Plains-Central Plains boundary | Bauxite | X | - | X | - | - | X |
| 2 | Georgia, South Carolina, Alabama, Mississippi, Tennessee | Atlantic and Gulf Coastal Plains (Kaolin belts) | Bauxite[3] | - | X | - | - | X | X |
| | | | High-aluminum clays | - | X | X | - | - | X |
| 3 | Alabama, Georgia, Tennessee | Southern Appalachian belt | Bauxite | - | X | - | X | X | - |
| 4 | Washington and Oregon | Coast Range and Columbia River | Lateritic Bauxite[4] | - | X | - | X | - | X |
| 5 | Washington and Idaho | Northern border region | High-aluminum (latah clay) | - | X | X | - | - | X |
| 6 | California | Central Valley | High-aluminum (lone clay) | - | X | - | X | - | X |
| 7 | North Carolina and Virginia | Southern Appalachian belt | High-aluminum clay | - | X | - | X | X | - |
| 8 | Maryland and New Jersey | Atlantic Coastal Plain | High-aluminum clay | - | X | - | X | X | - |
| 9 | Kentucky | Jackson Purchase | High-aluminum clay | - | X | - | X? | - | X |
| 10 | Tennessee | Western | High-aluminum clay | - | X | - | X? | - | X |
| 11 | Central Plains States | Carboniferous coal basins | Scattered aluminous clay in coal waste and deposits associated with coal | X | X? | - | - | - | X |
| 12 | Missouri | East central | Diaspore and high-aluminum clay | - | X | - | X | X | - |
| 13 | Pennsylvania | Clearfield | Diaspore and high-aluminum clay | - | X | - | X? | - | X |
| 14 | Wyoming | Laramie Range | Anorthosite | - | X | X | - | X | - |
| 15 | Wisconsin | Central region | Anorthosite | - | X | X | - | X | - |
| 16 | California | San Gabriel Mountains | Anorthosite | - | X | - | X | X | - |
| 17 | Idaho | Boehls Butte | Anorthosite | - | X | - | X | X | - |
| 18 | Minnesota | N. Lake Superior | Anorthosite | - | X | - | X | - | X |
| 19 | Montana | Stillwater Mountains | Anorthosite | - | X | - | X | - | X |
| 20 | Oklahoma | Wichita Mountains | Anorthosite | - | X | - | X | - | X |
| 21 | Virginia | Nelson County | Anorthosite | - | X | - | X | - | X |
| 22 | Pennsylvania | Southeastern | Anorthosite | - | X | - | X | - | X |
| 23 | New York | Adirondack Mountains | Anorthosite | - | X | X | - | X | - |
| 24 | Utah, Nevada, Colorado, Wyoming, Arizona, Washington | | Alunite, scattered deposits | - | X | X? | - | - | X |
| 25 | Colorado, Utah, Wyoming | Piceance Basin | Dawsonite in oil shale | - | X | X? | - | - | X |
| 26 | Florida | Phosphate belts | Aluminum phosphate rock | - | X | X? | - | - | X |
| 27 | Montana, Utah, Nevada, Arizona | Cordilleran belt | Alumina in copper mine waste dumps | - | - | - | - | - | X |

[1]Econ. = minable minerals; Subecon. = potentially minable materials (Tooker, 1979).

[2]Capability for satisfying long-term demands, if minable.

[3]Refractory bauxite now mined in Georgia and Alabama; only small tonnages mined in Mississippi and western Tennessee in past years.

[4]Mined for plant testing only.