CORPS OF ENGINEERS, U.S. ARMY
MISSISSIPPI RIVER COMMISSION

SURVEY OF SOURCES OF RECLAIM MATERIALS
LOWER MISSISSIPPI VALLEY DIVISION

SURVEY OF AGGREGATE SOURCES
LOWER MISSISSIPPI VALLEY DIVISION
REPORT NO. 4

TECHNICAL MEMORANDUM No. 6-283
WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

16 FEBRUARY 1949
CORPS OF ENGINEERS, U. S. ARMY

MISSISSIPPI RIVER COMMISSION

SURVEY OF SOURCES OF RIPRAP MATERIALS

LOWER MISSISSIPPI VALLEY DIVISION

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WATERWAYS EXPERIMENT STATION.

VICKSBURG, MISSISSIPPI

15 FEBRUARY 1949
Survey of Sources of Riprap Materials

Lower Mississippi Valley Division

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Survey of Sources of Riprap Materials
Lower Mississippi Valley Division

1. Authorization. This survey was authorized by the President, Mississippi River Commission, Vicksburg, Mississippi, in the 1st Indorsement, dated 6 August 1948, to correspondence from the Waterways Experiment Station, dated 4 June 1948, subject: "Survey of Aggregate Sources, Lower Mississippi Valley Division". By 1st Memorandum Indorsement, dated 23 September 1948, to a memorandum, dated 17 September 1948, from the Waterways Experiment Station, subject: "Survey of Aggregate Sources, Lower Mississippi Valley Division, Riprap and Derrick Stone" approval was granted for the proposal to deal with sources of these materials for all projects being considered in this survey in a single report.

2. Purpose. The purpose of this investigation was to locate sources of rock for use as riprap for the projects listed in paragraph 6, to secure samples of rock for testing as to its suitability for this purpose, and to ascertain quantities available.

3. Scope. As no adequate sources of rock suitable for riprap were known to exist in the states of Louisiana or Mississippi, it was necessary to investigate sources in adjacent states. Information was obtained on rock from 48 localities in the states of Oklahoma, Texas, Arkansas, Missouri, Louisiana, Kentucky, Tennessee, Mississippi, and Alabama. These 48 localities are shown on plate 1. Table 1 shows a summary of test data available on the various sites investigated for possible use as riprap materials. In several instances, data were not available and samples
were not secured for testing; however, the localities have been listed
for record purposes. Considerable data were secured from District Offices
on materials which had been investigated as riprap or as concrete aggre-
gates for various projects; these data have been incorporated in the table
and the testing agency listed. Also shown are results of tests performed
on samples secured by the Waterways Experiment Station in connection with
the present survey.

4. Sources of Data. Members of the Geology Branch, Soils Division,
Waterways Experiment Station, have made field examinations of quarry or
proposed sites for sources of riprap in the several states comprising the
area of this investigation. The personnel of the Construction Division,
Vicksburg District, had previously investigated sources of rock for bank
protection on the Blakely Mountain, Grenada, and Enid Dams. The Little-
Rock District Office has made surveys of sources of rock for engineering
uses. These data from both district offices have been made available for
this investigation. Data available from the files of the Soils and Con-
crete Research Divisions, Waterways Experiment Station, have been included.
The Memphis and New Orleans District Offices, and the Southwestern

Division Testing Laboratory have contributed names of operators of rock
quarries and quantities of stone used on specific engineering works.

Data were also obtained from the following organizations or sources:

a. Arkansas Geological Survey, Little Rock, Arkansas
b. Alabama Geological Survey, Tuscaloosa, Alabama
c. Division of Geology, State of Tennessee, Nashville, Tennessee
d. Maps and mineral bulletins published by the several states.
e. Owners and operators of quarries.
State Geological maps have provided the outcrop pattern of the formations as well as columnar and cross sections of the respective states. It is from these maps that plate 1 has been prepared. Figures 1 to 8, except 3, have been taken from columnar sections and show the stratigraphy of portions of the several states. No geological map of the state of Florida was available, so geology is not shown on that portion of this state which extends into the area of this survey.

5. Personnel. That portion of the work concerning geology and the principal portion of that concerned with physical testing was conducted by the Soils Division, Mr. W. J. Turnbull, Chief. The remainder of the work concerned with physical testing and the compilation of the report was conducted by the Concrete Research Division, Mr. Herbert K. Cook, Chief. This report was compiled by Mr. Bryant Nather, Chief, Special Investigations Branch from the geological report prepared by Mr. T. R. Mabrey, Geologist, Geology Branch, Soils Division; and the report on physical test results prepared by Mr. Woodland G. Shockly, Assistant Chief, Embankment and Foundation Branch, Soils Division.

6. Quantities of Materials Required. The quantities of riprap and derrick stone estimated to be required for the various projects included in this survey, as listed in the authorization for this work, are as follows:

<table>
<thead>
<tr>
<th>Project</th>
<th>Quantity, cu. yd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texarkana Dam</td>
<td>300,000</td>
</tr>
<tr>
<td>Morganza Control Structure</td>
<td>120,000</td>
</tr>
<tr>
<td>Ferrell's Bridge Dam</td>
<td>117,000</td>
</tr>
<tr>
<td>De Gray Dam</td>
<td>100,000</td>
</tr>
<tr>
<td>Project</td>
<td>Quantity, cu yd</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Kooringsport Dam</td>
<td>76,000</td>
</tr>
<tr>
<td>Old River Closure</td>
<td>70,000</td>
</tr>
<tr>
<td>Cooper Dam</td>
<td>54,000</td>
</tr>
<tr>
<td>Bayou Cocodrie Drainage Structure</td>
<td>8,000</td>
</tr>
<tr>
<td>St. John's Bayou Floodgate</td>
<td>4,100</td>
</tr>
</tbody>
</table>

A discussion of sources of riprap material for use on the St. John's Bayou Floodgate was included in "Survey of Concrete Aggregate, Filter Sands and Gravels, and Riprap - St. John's Bayou Floodgate", Survey of Aggregate Sources, Lower Mississippi Valley Division, Report No. 1, 10 September 1948, paragraphs 5a(2) and 7a. This report also contains detailed data on materials from sources 23 (Piedmont, Mo.), 24 (Williamsville, Mo.), and 27 (Cape Girardeau, Mo.) as described in paragraph 9 below.

7. **Types of Rock Considered for Use as Riprap Stone.** Stone for use as riprap must be fairly dense, free of bedding or joint planes along which breakage might occur, and relatively free of voids in which water might freeze, and thus cause spalling. Rocks composed largely of one mineral would be preferred over those composed of several minerals, whose different coefficients of expansion might create damaging stresses with temperature changes. Only certain types of rock meet these requirements. These are limestones, dolomites, sandstones, quartzites, and certain igneous and metamorphic rocks.

a. **Limestones.** Limestone is the most commonly used rock for riprap purposes. It is never pure calcium carbonate but carries varying proportions of dolomite, iron compounds, and numerous other minerals which
give it its color. Chert frequently is present as rounded nodules and upon weathering becomes dislodged. The dense, massive bedded limestones, with few bedding or joint planes are generally that most suitable for bank protection purposes. Its hardness is about 3.

b. Dolomites. Dolomites are similar to limestones except for a higher magnesium content. The magnesium-calcium ratio may vary considerably. Dolomite is so similar to limestone that chemical tests are necessary in order to distinguish it. Here, as with limestone, a massive, dense stone, free of bedding or joint planes, would be preferred. Dolomites are slightly harder than limestones and usually somewhat heavier.

c. Sandstones. Some sandstones are so poorly cemented as to be unsuitable for use as riprap. Others have undergone secondary cementation by siliceous ground waters, thus forming a quartzitic sandstone which is generally satisfactory for riprap.

d. Quartzites. Quartzite is a metamorphic rock, generally a sandstone which has undergone secondary cementation. The cementing material is usually silica, but other minerals may give the rock its color. By definition, cementation in a quartzite is so complete that, when the rock is broken, fractures pass indiscriminately through the sand grains; whereas, in sandstones, breakage will occur around these grains. Fracturing is uneven, splintery, or conchoidal; and luster is often vitreous like that of quartz. Quartzites are about the hardest of the common rocks. A good example of a quartzite is the Arkansas novaculite.

e. Granite. This is a granular rock made up of feldspars and
quartz with minor quantities of hornblende, mica, and other minerals. Feldspars generally predominate and give the rock its color. Granites range from very sound rock to that which would be unsatisfactory for riprap purposes. A very good cue on the soundness of granite is the appearance of quarry faces exposed to the weather for several years. Exfoliation is usually quite pronounced on unsound granites.

f. Nepheline Syenites. Nepheline syenites have been upthrust from great depths south of Little Rock and in the Magnet Cove area of Arkansas. The rocks are composed of crystalline, alkaline feldspars and nepheline, with minor quantities of the other minerals, especially mica. However, it is too uncommon to be of much commercial importance. Where available, it would make an excellent stone for bank protection use.

3. Geology. Table 2 shows the geological eras, periods, and epochs with an approximate time scale. Note that each figure should be multiplied by 1000 years. The periods are frequently broken into lower, middle, and upper divisions, and divided into formations which are given geographical names. Correlations from state to state have been made by fossil content and lithology. Portions of the stratigraphic sections of the several states are shown on figures 1 to 3, and indicate the formations from which quarries secure rock. A brief description of the eras and periods is given to permit comparison of the types and thicknesses of the sediments deposited in various sections of the several states comprising this investigation, and structural movements resulting from this unequal deposition.
a. Pre-Cambrian (Archeozoic - Proterozoic). The only rocks of this age in the area of this study, form the so called "crystalline" area of east-central Alabama. They are all igneous and metamorphic rocks, uplifted by Appalachian folding. Rocks of this group, granites of Oklahoma and nepheline syenites of Arkansas, are indicated on plate 1 by the symbol "PC".

b. Cambrian - Ordovician. In early Cambrian time, a synclinal trough from the northeast continued through eastern Alabama and turned westward through the Ouachita and Arbuckle regions. Into this sea great thicknesses of sediments were deposited. The continued deposition in the synclines caused a downwarping of these areas with a compensating uplift of adjacent land surfaces. These uplands were a source of materials, which when eroded were again deposited in the low areas. Thus, there has been a constant readjustment of the surface, under load, causing encroachments and retreats of the seas, so in the area of this investigation, marine and continental deposition varied in type and thickness throughout the geologic eras. Some 160,000,000 years had elapsed from the beginning of the Paleozoic era to the end of the Ordovician. Meanwhile some 12,000 feet of limestones and dolomites including about 3,000 feet of shale had accumulated in east-central Alabama and about 3,500 feet in central Tennessee. In Alabama a narrow highland must have existed for a long period of time on which is the present city of Birmingham. Just east of this ridge is the Cahaba River and a coal field of the same name. Sediments differ in lithology and thickness on either side of this ridge. Figure 1 shows the stratigraphy of the Cambrian, Ordovician, and Devonian to the southeast. The wavy lines in the columnar section indicate
unconformities which had been erosional surfaces. Figure 2 shows the section of the same geologic age northwest of the ridge. Note the many differences in stratigraphy. During the Cambrian and Ordovician series, about 10,000 feet of limestones and dolomites were laid down in the Arbuckle Mountain region of Oklahoma. Figure 3, taken from a photograph of a sign along a highway north of Ardmore, depicts the relationships of the formations involved in the Arbuckle Mountain folding. Note the same formations on either side of the porphyry core. Erosion has cut out these formations as they were forced upward. The thickness of the rocks exposed from the porphyry to the base of the Carey shale is about 9,700 feet. This deposition of calcareous deposits was continuous but thinned northeastward, north of the Ouachita region, and is represented on the south and east flanks of the Ozarks by about 2,500 feet of dolomites and limestones. Figure 4 indicates the formations present in northern Arkansas while Figure 5 shows those existing in southeast Missouri. There was no other period in geologic history when such great thicknesses of calcareous sediments accumulated in this area as during the Cambrian and Ordovician. In contrast with the great thicknesses of limestones and dolomites which accumulated over most of the area of the survey, some 4,700 feet of sands and shales of continental origin were deposited in the Ouachita Mountain region of Arkansas. Figure 6 shows the dominantly sand and shale section of the Cambrian and Ordovician series which may be compared with that of northern Arkansas, Figure 4, which is almost entirely calcareous. Quarries in Oklahoma, Missouri, Tennessee, and Alabama, produce rock acceptable for use as riprap from the limestones and dolomites of
Cambrian and Ordovician age.

c. Silurian. An elevation of the surface in late Ordovician left shallower and less extensive seas which resulted in deposition of thinner deposits during Silurian time. About 200 feet of limestone accumulated in Kentucky, northern Arkansas (Figure 4), and southern Oklahoma, but only 80 feet in southeastern Missouri (Figure 5). In central and west Tennessee, 200 feet of limestone was laid down while in the eastern part of the state some 1,500 feet of shale and sandstone, the latter often ferruginous, was deposited. In Alabama, 360 feet of shale, including the Red Mountain iron ore, was formed northwest of the Cahaba coal field (Figure 2). With iron ore, coal, and limestone available nearby, Birmingham has become the iron and steel center of southern United States. Slag from the manufacture of iron and steel is too porous and too light in weight to be a source for riprap. In the Ouachita region of Arkansas, 1,500 feet of sand overlain with 300 feet of shale, was deposited (Figure 6).

d. Devonian. Differential warping and additional retreat of seas from this area restricted marine deposition for this period. The Chattanooga shale, not over 30 feet thick, was laid down over most of Alabama (Figures 1 and 2) and extended into central and west Tennessee. It thickened to 250 feet in north Arkansas where it contained sand, limestone, and chert. The Arkansas novaculite in the Ouachita region was deposited during this time and reached a maximum of 350 feet in thickness (Figure 6). This is the only stone of Devonian age which is
quarried. In the Arbuckle region of Oklahoma, the Devonian is represented by about 600 feet of chert. This is the Woodford formation shown on Figure 3. In southeastern Missouri, about 400 feet of limestone was formed (Figure 5). The end of the Devonian was marked by slight withdrawal of the seas and local crustal disturbances, which caused some mountain building in northeastern Alabama. Considerable faulting occurred in southeastern Missouri, but no folding of the strata. There was some uplift of the Ozarks. The outcrop of the formations from Cambrian to the top of the Devonian are shown on plate 1 with symbol "O".

**Mississippian.** There is an unconformity at the base of the Mississippian rocks, but submergence is indicated by thicker beds, much of which is limestone. In east central Alabama 2,400 feet of limestone changing to shale at the top, accumulated as 2,700 feet of shale was deposited in the northwest portion of the state. Figures 1 and 2 show the stratigraphy southeast and northwest of the Cahaba coal field. Several unconformities exist which denote erosional surfaces with hundreds of feet missing (Bick dolomite below Copper Ridge dolomite), the Panor limestone of upper Mississippian wedging into the Floyd shale, as well as other discrepancies. In central and west Kentucky, east of the Tennessee River 3,100 feet of limestone with some shale and sandstone near the top was laid down. Figure 7 shows the stratigraphy of the Devonian and Mississippian in this area. In Missouri, Figure 6, about 800 feet of Mississippian limestones accumulated. These beds thickened southward into north Arkansas where some 1,500 feet of limestone including several sandstone beds in upper portion were deposited. This section of limestones,
and sandstones is shown on figure 4. A good many of these Mississippian limestones carry some chart. About 6,000 feet of shale overlain with 6,000 feet of sandstone and interbedded shale was deposited in the Ouachita region of Arkansas. These formations are named the Stanley shale and Jackfork sandstone. The base of the Jackfork sandstone, which furnishes some rock for bank protection is about 6,000 feet above the Hot Springs sandstone near the top of figure 6. In the Arbuckle Mountain region of Oklahoma, one bed, the Sycamore Limestone about 160 feet thick was deposited during the Mississippian series (Figure 3). A widespread emergence of the continent occurred in late Mississippian with some erosion. Faulting occurred in southern Illinois and western Kentucky. Limestones of Mississippian age acceptable for use as riprap are quarried in Oklahoma, Arkansas, Missouri, Kentucky, Tennessee, and Alabama. Narrow belts of these limestones outcrop along the walls of a few stream valleys in the extreme northeast corner of the state of Mississippi (Plate 1), but are not quarried.

C. Pennsylvanian. Due to the emergence of the surface in late Mississippian and subsequent erosion, Pennsylvanian deposits were laid down on an unconformable surface, angular where warping had accompanied the uplift. An interesting character of the deposits is the repeated alternation of marine and non-marine sediments. It is thought that seas were shallow, not over 100 feet deep. Many of the limestone beds may be traced on the surface for 500 miles. Conglomerates occur at the bases of some of these formations and indicate that streams were, in part, the
transporting agents. Some of these filled stream valleys in Missouri are depicted on figure 2. Shales of Pennsylvanian age are 7,300 feet thick in east central Alabama, but thin to 2,600 feet in the northwestern part of the state. In central Tennessee, they are 4,500 feet in thickness. In western Kentucky, east of the Tennessee River, the shales are about 350 feet thick and in Missouri, 1,750 feet. In northern Arkansas, the shale is 1,500 feet thick, but in southwestern Arkansas in the Ouachita region, it thickens to 5,000 feet and continues westward into Oklahoma.

It is composed of alternating sandstones and shales and is named the Atoka in both states. Sandstones from the Atoka formation have been used for riprap and in concrete aggregate. Overlying the shale, fossiliferous limestones from 300 to 500 feet in thickness formed in western Missouri and Kansas. South of the Arbuckle region of Oklahoma, over 4,000 feet of limestone was deposited. The Pennsylvanian limestones are not quarried for riprap. The thickness of the Pennsylvanian deposits range from 1,000 to 2,000 feet in parts of the interior region to more than 25,000 feet in the Ouachita geosyncline in Arkansas and Oklahoma. Post-paleozoic erosion has removed a large part of the Pennsylvanian deposits in most of the mountainous regions of eastern Kentucky, Tennessee, and Alabama, but in places the remaining beds are more than 10,000 feet thick. In late Pennsylvanian, intense folding began in the Arbuckle and Ouachita regions, with much deformation and faulting. The Ozarks were uplifted but without folding. Erosion has removed nearly all of the Pennsylvanian deposits from this area. Some structural movement began in the mountains.
of eastern Kentucky, Tennessee, and Alabama during Pennsylvanian time but continued into the Permian. The outcrop pattern of the Pennsylvanian and Mississippian formations are shown on plate 1 with the symbol "C".

**c. Permian - Triassic - Jurassic.** Rocks of these series are not present in the area of this investigation. It was during the Pennsylvanian, however, that the Appalachian Mountains became most intensely folded, with normal faults and overthrust, producing narrow sharp parallel ridges trending in a northeast-southwest direction which ended in east-central Alabama. This deformation and subsequent erosion exposed the "crystalline" area of east-central Alabama which is composed of gneisses, quartzites, schists, granites and slates, igneous and metamorphic rocks. Some 90,000,000 years elapsed from the end of the Pennsylvanian until the beginning of the Cretaceous when seas again encroached northward from the Gulf of Mexico.

**h. Cretaceous.** The areal extent of deposits of this age is shown on plate 1 with the symbol "F". Few hard rocks were formed, though ironstone or ferruginous sandstones occur in some formations. It was during the Cretaceous that the nepheline syenites and related rocks were upthrust south of Little Rock and in the Magnet Cove Area of Arkansas. These nepheline syenites are an excellent stone for riprap.

**i. Tertiary.** The outcrop pattern of the Tertiary is indicated on plate 1 with the symbol "T". Only one formation of this age, the Vicksburg group of Oligocene age contains limestone, but this is more marl than limestone and is generally not suitable for bank protection purposes. Siltstones from the Catahoula formation of Miocene age have
proven unsatisfactory for engineering usage. Ferruginous sandstones of
the Tallahuta formation, Claiborne group of Eocene are outcrop in places
and might be a source of riprap.

j. Pleistocene. This is the period of glacial and interglacial
stages, with the formation of terraces whose basal sections are composed
of unconsolidated sands and gravels. The history of these terraces is
discussed in detail in the report "Geological Investigation of Gravel
Deposits in the Lower Mississippi Valley and Adjacent Uplands", which
will be completed in the near future. The terrace deposits and their
origin are briefly discussed in paragraph 6 of the report "Survey of
Concrete Aggregate, Filter Sands and Gravels, and Erosion Backfill -
Vicksburg Floodwall", Survey of Aggregate Sources, Lower Mississippi
Valley Division, Report No. 3, 1 February 1949.

k. Recent. The Recent is considered to be that period which
began with the waning of the last ice sheet, the Late Wisconsin. It be-
gain about 30,000 years ago. The deposits are alluvium filling stream
valleys which are normally underlain with loose sands, and or gravels.
No rock suitable for riprap stone was formed during this period.

9. Description of Sources. It will be noted that the descriptions
of sources as numbered below correspond to the numbering on plate 1.
Details of the rock sources are given below. It will be further noted
that the rock of each quarry is designated as acceptable, "a", unaccept-
able, "u", or status unknown, "o", as the case may be. Such rating is
based on actual testing of samples or on informative experience, and
cannot of course be absolutely guaranteed to prevail for unlimited quantities of rock. Sketches of various quarries are shown on figures 9 to 20. These figures furnish a general picture of the location layout of the quarry. Attention is directed to the fact that many of the quarries which show the rock as "status unknown" are located at such distances that it was not believed economically justifiable for the purposes of this report to sample and test the rock, since satisfactory rock is available within much shorter distances.

1. Rayford Stone Company, Oklahoma City, Oklahoma, o. W. Dohe is the owner. The quarry is located on Santa Fe Railroad about 5 miles south of Davis, Murray County, Oklahoma. Mr. Kattis is plant superintendent. One quarry is about ½ mile from railroad and 150 feet higher in elevation. They are operating a face of about 80 feet high with crushing equipment at site. All rock is hauled by truck. The formation is tentatively correlated with the Sycamore limestone of Mississippian age. A second quarry is at railroad level with crushing equipment and facilities for loading on cars. This quarry is in the Hunter limestone of Silurian and Devonian age. These formations are shown on figure 3. Reserves of rock are quite large. No one at plant could give data with regard to production or use of crushed stone. No rock samples were secured.

2. Dolose Bros. Company, P.O. Box 1273, Oklahoma City, Oklahoma. This is the Big Canyon quarry on the Santa Fe Railroad about 10 miles south of Davis, Murray County, Oklahoma. The rock is the
Arbuckle limestone of lower and middle Ordovician age, which is shown on figure 3. Face is about 300 feet in length and 30 feet in height at center. Sketch of quarry is shown on figure 3. The limestone is medium gray in color, very dense and massive bedded, with an occasional shale parting. Paint jointing is normal to bedding. Formations dip about 40° west. Some of this rock was used on Denison Dam but normal output is reserved for ready-mixed concrete in Oklahoma City and ballast for railroads. The reserves are quite large.

3. Rock Products Manufacturing Company, P. O. Box 81, Ada, Oklahoma, a. Mr. William Ryder is president of the company. Plant is at Ryder Station on Frisco Railroad, near Troy, Murray County, Oklahoma; quarry is 3 miles west with narrow gauge railroad to site. The rock is the Royer dolomitic marble of Upper Cambrian age, and is a remnant covering several hundred acres which lies on granite. The rock is a light, buff gray in color, crystalline, very massively bedded and contains numerous small pits or voids. Vertical joint systems permit weathering along these planes. It is nearly a pure dolomite. This remnant of the Royer marble lies east of the cross-section through the Arbuckle Mountains, so is not shown on figure 3. The entire supply of crushed stone is used for flux by steel mills in Texas. A plant for the manufacture of rockwool is under construction in Ada, and when completed, will take all the production of this plant. The reserves will last many years. Sketch of quarry is shown on figure 10. Figure 10A is a photograph of quarry face showing nature of this dolomitic marble.
4. Dolese Bros., P. O. Box 1273, Oklahoma City, Oklahoma, a.

Quarry is near Ermida, Johnston County, Oklahoma. Mr. A. L. Morgan
is plant superintendent. The rock is the Viola limestone of middle and
upper Ordovician age (Figure 3). This is quite a large quarry with a
face almost 2000 feet long and 100 feet high at center. The upper sur-
face follows the dip of the beds which form a slight anticlinal fold.
The stone is a light buff gray in color, massive bedded, and dense, with
calcite, in places, filling thin veins and fractures. Vertical joint
systems tend to make the rock break with smooth faces along these planes.
Sketch of quarry face is shown on figure 11. Operator supplied the Denison
Dam with 90,000 tons, 2\(\frac{1}{2}\)" rock, 250 cars 6" rock; and 12,000 tons of
crushed limestone for concrete for power house. Normal output is used
in ready-mixed concrete plants in Oklahoma City and as ballast for rail-
roads. The reserves are very large.

5. St. Clair Lime Company, P. O. Box 52, Sallisaw, Oklahoma, a.

Data was secured from New Orleans District. This company was a source of
riprap stone - 25 pounds to 6 tons - for the E & N jetties, Belle Fasse,
Bayou Lafourche, Louisiana. Quarry was not visited and information ob-
tained other than use indicated, was meager.

6. Vicinity Deuerfield, Texas, u. This area was investigated
in 1940 as a source for riprap for the Wallace Lake Dam. The rock is
a sandstone, in part corrasponlous and occurs in the Tejas formation of
Cretaceous age. It caps many of the hills east of Deuerfield and is
locally used for road metal. In general it is not recommended for use
as riprap because of its varying quality and large pore structure.
7. Vicinity Marietta, Texas, u. This is a similar case to the one above. It, too, is a ferruginous sandstone of the same formation. Figure 5A is a photograph of an outcrop of ironstone near Marietta.

8. Servtex Materials Company, P. O. Box 729, New Braunfels, Texas, a. Data secured from New Orleans District. This company was a source of stone for riprap at three highway and two railroad bridges on Charenton Drainage Canal and jetties at Calcasieu Pass, Louisiana. One half of stone was from 100 to 200 pounds, and one half from 200 to 500 pounds in weight. Further specific information not available, site was not visited.

9. Potter, Arkansas, a. This is an abandoned quarry from which the L & A Railroad secured stone for bank protection. It was investigated as a source of rock for riprap for the Wallace Lake Dam. It is a hard, dense, siliceous sandstone, breaking with flat faces in two definite joint planes with angles of about 75° and 105°. Although tests proved it suitable for use as riprap, the limited supply and the fact that it broke into rather small blocks would not warrant reopening the quarry. This is a sandstone bed of the Atoka formation of Pennsylvanian age. Stratigraphically, the base of the Atoka formation is about 12,000 feet above the Hot Springs sandstone which is shown on figure 6. The base of this shale correlates with the Caney shale as shown on figure 7 in the Arbuckle region of Oklahoma. The Little Rock District Office secured sandstones from the Atoka formation for riprap on the Blue Mountain and Timrod Dams and some of the sandstone provided a suitable concrete aggregate.
10. **Harrison, Boone County Lime Products Company, Arkansas.**

a. This is limestone of the Boone Formation of Mississippian age. This formation appears on Figure 4. Data are from the Little Rock District Office.

11. **Reynolds Aluminum Company, Guion, Arkansas.** a. Data are from the Little Rock District Office. The rock is the Clattin-Fernvale limestone of middle and upper Ordovician age and appears on Figure 4.

This company does not quarry from the limestones of the lower Ordovician series, however, several of these are good riprap stone as evidenced by their use from sources close to the dams discussed in the remainder of the paragraph. The Norfolk Dam used rock from the Cotter dolomite and Everton limestone. The Bull Shoals Dam now under construction will secure stone from the Everton for aggregate 7 miles away, and rock from the Cotter dolomite for riprap. At Table Rock Dam, the Jefferson City dolomite forms the abutments and will be used in the proposed rock-filled dam. Aggregate will come from the Boone limestone.

12. **Big Rock Stone & Materials Company, Foot of Ashley Street, Little Rock, Arkansas.** a. Investigated as source of riprap for the Blakely Mountain Dam. This company has a large quarry in North Little Rock in sandstone of the Jackfork sandstone, upper Mississippian in age. The west face of the quarry is about 130 feet in height. The upper 30 feet is sandstone and the underlying 30 feet quartzite sandstone. Shale parting between the beds facilitate quarrying. Formations are about horizontal and Figure 8M shows the bedding of this face. Normally the sandstone is used for aggregate for concrete and other uses, but the company
has furnished stone for bank protection to the Vicksburg and Memphis Districts. This is an excellent rock for this purpose. Reserves are unlimited.

13. Big Rock Stone & Materials Company, Little Rock, Arkansas, a. Quarry site is 2\(\frac{3}{4}\) miles south of Little Rock on U. S. Highway 167. This is an old quarry which has not been operated for several years. It is a huge mass of rock covering hundreds of acres which is named "Granite Mountain". Figure 12 is a plan and profile of the quarry site taken from a contoured map submitted by the company. Two types of nepheline syenite are present. The lower portion is very coarsely crystalline with light grayish almost white feldspars and darker gray feldspars giving the rock a light colored mottled appearance. Many of the crystals are slender, narrow, and elongated. Overlying this is a coarsely crystalline medium gray nepheline syenite. The crystals are flat rather than elongated and glisten when light reflects from faces. This rock continues to the top of the hill which is about 150 feet higher than the floor of the quarry. Core holes were made into this upper zone by the company and a small test area blasted off. Figure 12A is a photograph of the quarry face and shows the approximate contact between the dark and lighter colored stone. Both the light and dark colored stone are suitable for riprap, but the operator would prefer to quarry from the upper zone which would permit constructing a ramp over the highway to the railroad siding. The Big Rock Stone and Material Company would probably be willing to re-open this quarry if an order sufficient to warrant operation were secured.
Reserves are huge.

14. Property of Dierks Lumber Company, Section 20 - T2S - R20W; Garland County, Arkansas, a. Investigated as a source of riprap for Blakely Mountain Dam. This is probably the Hot Springs sandstone as shown on figure 6. It forms the basal member in this immediate area, of the Mississippian period. The sandstone varies much in grain size, cementation and pore space, but tests showed it to be tentatively acceptable. Further testing would be required based on specific job requirements.

15. Property of Jesse Caldwell, Section 34 - T1S - R20W, Garland County, Arkansas, a. This site was investigated as a source of riprap for the Blakely Mountain Dam. This is a limestone lentil occurring in the Bigfork chert of middle Ordovician age and appears on figure 6. Tests proved it suitable for riprap and in late January 1949 core holes were being made in the limestone to determine quality and quantity available. This may prove to be the nearest source of riprap for the Blakely Mountain Dam.

16. Jack Knight, Malvern, Arkansas, a. This is an old quarry on the property of the Rock Island Railroad in the Magnet Cove area of Arkansas, investigated as a source for riprap for the Blakely Mountain Dam. The site of the quarry is adjacent to the property of Jack Knight and the rock has been identified by the Arkansas Geological Survey as a coarse grained (St. Jo type) nepheline syenite. Figure 13 is a sketch showing quarry face and sample locations. This nepheline syenite occurs as dikes intruded into a mass of leucite syenites with other dikes of fine grained nepheline syenites and still others of metamorphic rocks.
Members of the Arkansas Geological Survey have mapped from surface boulders and outcrops the approximate contacts between the several types of igneous and metamorphic rocks of the Magnet Cove area. Figure 14 was traced from a portion of this map. It shows the distribution of the several types of igneous and metamorphic rocks and the boundaries of the Jack Knight property. The nepheline syenite (St. Jo type) is a coarsely crystalline rock composed of feldspars, mica, nepheline and other minerals in small proportions. The feldspars are tabular in shape and as the rock contains no quartz, stresses set up by temperature changes would be insignificant. Joint planes from 3 to 6 feet apart would facilitate quarrying. Tests proved it to be a superior stone for riprap. As these related rocks were formed from a deep seated magma of about the same mineral composition, it would be assumed that the leucite syenites and the fine grained nepheline syenites should be just as sound stone as the coarse grained syenites. This is believed to be true and would make the supply of reserve stone almost unlimited. While quarrying costs would be higher than for limestone, this area is the farthest south in Arkansas and would be a logical competitor with the quarries in Oklahoma for proposed engineering work in northeastern Texas and farther south in the Lower Mississippi Valley Division.

17. Coogan Gravel Company, Peoria, Illinois, a. Quarry is in the vicinity of Butterfield, Arkansas. This company quarries novaculite, an extremely fine grained quartzite of Devonian age. It is shown on figure 6. The rock is practically all one mineral - quartz, is hard,
and resists weathering. Its suitability for riprap is dependent entirely on whether or not the proper sizing can be obtained. Due to its nature, it tends to shatter badly. Figure 14A is a photograph of the novaculite in this quarry and the fracturing is quite evident. The steep angles of the bedding are due to the deformation of the Ouachita Mountain folding. At present the entire output is for railroad ballast. The reserves are unlimited.

18. Vicinity Amity, Clark County, Arkansas, a. This is an area about 4 miles south of Amity where the Jackfork sandstone has been faulted up to form a ridge. As a railroad is nearby, the site was investigated for this study. It would be necessary to build a half-mile spur and remove considerable overburden in heavy timber, to secure access to the stone. Unless large quantities were quarried and a constant market available, it would not appear feasible to develop this site in competition with others in operation. Quartzitic sandstone from the Jackfork formation will be used for bank protection riprap at the Harrows Dam, the rock being obtained adjacent to the site.

19. Coochie Brake, 14 miles southwest of Winnfield, Louisiana. This site was investigated for a source of riprap for the Wallace Lake Dam in 1940. It is an area about 150 feet wide and 400 feet long, where limestone had been upthrust by a salt plug. Borings were made by the Vicksburg District to determine depth to bed rock, but quantities available and the long haul to railroad, prevented its adoption as a source of rock for riprap.

20. Carey Salt Company, Winnfield, Louisiana, u. This area was
investigated as a source of rock for bank protection for the Wallace Lake Dam in 1940. It is limestone upthrust by a salt plug. The rock, a quite impure limestone and much fractured, formed an escarpment about 20 feet high and extended in an arc about half a mile. At that time, the Solvay Process Company of Baton Rouge, Louisiana, had a lease on the property and the entire supply was shipped to Baton Rouge. The quantity of the rock is quite limited and its quality is poor.

21. **Vicinity Harrisonburg, Louisiana, U.** Samples of siltstone were secured in 1940 from Eocene sediments northwest of Harrisonburg for testing for riprap on the Wallace Lake Dam. They failed in the first freezing and thawing test.

22. **Carthage Marble Company, Independent Gravel Company, Carthage, Missouri, U.** Date from Little Rock District Office. Test data are available on limestone of the Burlington formation, Mississippian age, from this source.

23. **Piedmont, Missouri, U.** Abandoned quarry north of Piedmont. Rock is Pre-Cambrian granodiorite porphyry. Test data are available.


25. **Delta, Missouri, U.** Abandoned quarry 6 miles west. The rock is a dolomite of the Jefferson City formation, middle Ordovician in age. It is not so closely jointed and less weathered than the stone at Delta. The Jefferson City dolomite is shown on Figure 5. No test data are available.

26. **Near Delta, Missouri, U.** A small quarry is producing stone
of the Jefferson City dolomite of middle Ordovician age. The rock is closely jointed and badly weathered. Figure 147 is a photograph of this quarry showing the nature of the rock. The Jefferson City formation is shown on figure 5. No test data are available.

27. Federal Materials Company, Cape Girardeau, Missouri, a. This company is quarrying the Plattin limestone of upper Ordovician age. This formation is shown on figure 5 and figure 146 is a general view of the quarry. In 1943, the Memphis District was supplied with 6,000 cubic yards of small riprap stone from this source.

28. E. C. Schroeder Company, Isbell, Alabama, a. Proposed quarry is 3.5 miles south of Edyville, Kentucky on State Highway 73. This is a source of riprap for the Grenada Dam, in case the quarry at Isbell, Alabama, lacks sufficient quantities for this contract. The rock is a limestone of the Pisces group of the lower series, lower Mississippian in age and is shown on figure 7. Plan and face of quarry are shown on figure 13 and 15A is a photograph of the exposed face. This is an outcrop of limestone at least 2,500 feet in length which slopes steeply upward to about 140 feet from the base. The present quarry face is about 70 feet high and 175 feet in width. It has not been operated for about 5 years. The limestone varies from medium to dark gray in color, is quite dense and massive, and horizontally bedded, and carries varying amounts of chert.

29. Cerulean Stone Company, Cerulean, Kentucky, a. This is a limestone of Mississippian age. Cerulean is on the contact between the
lower and upper Mississippian. The stone could be either from the Keramec or Chester groups as shown on figure 7. No test data are available.

30. Murphy Brothers, Bowling Green, Kentucky, o. This rock is probably a limestone of the Keramec group of Mississippian age, which is shown on figure 7. No test data are available.

31. Southland Lime Company, Erin, Tennessee, o. This rock is also probably a limestone of the Keramec group of Mississippian age. No test data are available.

32. East Tennessee Limestone Company, Corron, Tennessee, o.
This rock is likewise a limestone of the Keramec group of Mississippian age. No test data are available.

33. Franklin Limestone Company, 612 10th Avenue, North, Nashville, Tennessee, o. The Denley quarry is 12 miles southeast of Nashville.
This company has contract for riprap, Enid Dam. The rock is the Carters limestone of Ordovician age and correlates with the Chickamauga limestone of Alabama, as shown on figure 2. It is generally light gray in color, very finely crystalline and massive bedded, but breaks along bedding planes which are about horizontal. Faint joint systems normal to bedding are present. Figure 16 is sketch of quarry and shows sample locations; figure 16A is a photograph of a face 56 feet high which has weathered for ten years. Figure 16B is a photograph of a sawed etched surface of a sample from this quarry.

34. Thompson - Heinman, Sparta, Tennessee, o. This quarry is probably securing limestone from the Chester - St. Louis group of Mississippian age. No test data are available.
35. **Franklin Limestone Company, 612 10th Avenue, North, Nashville, Tennessee, e.** Quarry is 3 miles south of Columbia, Tennessee, on State Highway 64. This is a second quarry from which the operator will furnish riprap stone for the Emory Dam. A new face was opened for this rock and Figure 17 shows the size of this face on 2/12/49. Figure 17A is a photograph of this face taken about 6 months earlier. This is the same limestone (Carter's) as at the Penley quarry (33), but some chert occurs in lower beds which will not be quarried. Figure 17B is a photograph of a sawed etch surface of a sample from this quarry.

36. **Gowan Cement Company, Cowan, Tennessee, e.** This quarry is in Chester - St. Louis limestones of Mississippian age which are shown on Figure 7. No test data are available.

37. **Gapar Lime Company, Sherwood, Tennessee, e.** This quarry is in the Chester - St. Louis limestone of Mississippian age which are shown on Figure 7. No test data are available.

38. **Oolitic Lime Company, Anderson, Tennessee, e.** This quarry is probably in the oolitic zone of the equivalent Bangor limestone of Alabama as shown on Figure 2. It is in the Chester group of upper Mississippian in age. No test data are available.

39. **Vicinity Greenbend Dam, e.** Ferruginous sandstones of the Tallahatchie Formation, Claiborne group, Eocene, Tertiary, outcrop along hillsides in the vicinity of the Greenbend Dam and Reservoir. Tests made on samples from this source indicated that they are satisfactory. However quality of acceptable stone is probably limited.
40. Vicinity Vicksburg, Mississippi. a. Limestones and marls of the Oligocene group, Tertiary, outcrop for several miles along the bluffs in the vicinity of Vicksburg. Though the limestones are quite impure and not as dense as limestones of older geologic ages, certain beds of this group would serve as riprap. The majority of the stone, however, is indefinitely unsatisfactory.

41. Alabama Asphaltic Limestone Company, 407 Farley Building, Birmingham, Alabama. Quarry is in the vicinity of Yaggerum, Alabama. This company furnished 20,000 tons of large stone for the Sardis Dam, after which quarry was abandoned. The company is now quarrying only asphaltic limestone from the Gasper formation, lower Chester group, upper Mississippian, which is shown on figure 2. Asphaltic limestone would not serve as riprap.

42. Rockwood Alabama Stone Company, Rockwood, Alabama. James Lord is president of the company. Quarry is at Rockwood. The company is quarrying cut stone from an oolitic zone of the Bangor limestone, lower Chester group, upper Mississippian. This formation is shown on figure 2. Stone is also being quarried from the same formation for agricultural lime. They have not furnished rock for riprap.

43. E. C. Schroeder Company, Isbell, Alabama. Quarry is 0.3 mile south of Isbell. Operator has contract for riprap, Grenada Dam. This quarry was developed for this contract. The rock is the Bangor limestone, lower Chester group, upper Mississippian in age. It is mottled gray in color, very finely crystalline and massive, with horizontal bedding.
Calcite fills veins and fractures and occurs in places, as flakes. This formation is shown on Figure 2. Figure 18 is a sketch of the quarry showing locations of the first set of samples. Figure 18A shows locations of the second set of samples and Figure 18B is a photograph of the south half of the quarry from which rock will be secured. This photograph was taken on 20 November 1947, before quarrying operations began.

44. J. J. Schiely Company, 1101 Snelling St., St. Paul, Minnesota, a. This company opened a quarry at Bangor, Alabama, and furnished much of the riprap stone for the Sardis Dam. This is the type section of the Bangor limestone, which is lower Chester, upper Mississippian in age. Operations ceased with completion of the contract. There is still an estimated 1,000,000 tons at this site and company would like to bid on riprap.

45. Alabama Aggregate Company, 304 S. 41st Street, Birmingham, Alabama, a. Quarry is at Cobb City, 8 miles southeast of Gadsden, Alabama. Rock is the Chickamauga limestone of Ordovician age. It varies from light to dark gray in color, is dense and massive but shows some evidence of bedding. Two irregular joint planes are about normal to one another and to bedding. Dip is about 45° southeast. This quarry site lies between two faults and some slippage may be observed on face. This formation is shown on Figure 2, and Figure 19 is sketch of quarry showing sample locations and other pertinent data. This company supplied the Mobile District with stone up to 8 tons in weight for jetties at Panama City, Florida. The New Orleans District used stone from this quarry for the E & W jetties, Belle Pass, Bayou Lafourche, Louisiana. Normal output goes to steel mills
for flux and agricultural lime which is seasonal. Reserves are quite large.

46. Alabama Aggregate Company, 304 South 41st, Birmingham, Alabama, a. Quarry is near Pelham, 12 miles southeast of Birmingham. Quarry is in the Sowela limestone, lower Ordovician in age. This formation is shown on figure 1 and figure 20 is sketch of quarry showing sample locations and other data. Rock is light to medium gray in color, very dense and massive bedded in beds to 3 feet thick. Two sets of joint planes are normal to each other and to bedding. Formation dips about 50° southeast. Operator has supplied the Mobile District Office with 2100 tons, 10 to 150 pound stone for riprap on Pearl River Locks and 1,500 tons of the same size to Sylacauga, Alabama. Normal production is for railroad ballast and flux for steel mills.

47. Alabaster Stone and Limestone Company, Syluria, Alabama, o. No data are available.

48. Alabama Marble Company, American Life Building, 1st Avenue, 18th Street, Birmingham, Alabama, o. Quarry is at Sylacauga, Alabama. No data are available.

10. Tests Performed. Because of the variety of sources from which data were obtained, there was little consistency in the types of tests performed on any given sample. The most complete data were obtained on those samples tested by the Waterways Experiment Station (Sources No. 2, 3, 4, 12, 13, 17, 45, and 46). In general, information was obtained on unit weight, absorption, abrasion, and soundness. The following paragraphs
describe the tests performed or refer to standard tests which were used by the Waterways Experiment Station in testing the rock. In so far as can be determined, the test procedures outlined are also applicable to tests performed by other agencies and reported in table 1.

a. Unit Weight. The value shown in the table is unit weight in pounds per cubic foot, obtained by first weighing the sample in air and then weighing under water.

b. Absorption. Tests were conducted according to applicable parts of ASTM Designation C 127-42. The Waterways Experiment Station tests were made on the portion of the sample prepared for the Deval abrasion test.

c. Deval Abrasion. Tests were conducted in accordance with ASTM Designation D 2-33.

d. Los Angeles Abrasion. Tests were conducted in accordance with ASTM Designation C 131-46. Table 1 shows pertinent notes designating whether grading "A" or grading "B" was used in the test. In some instances the percentage of wear after both 100 and 500 revolutions is shown. Additional Los Angeles Abrasion test data are given in table 1A.

e. Sodium Sulfate Soundness. Tests were conducted according to parts of ASTM Designation C 83-46T applicable to the sodium sulfate test. In general, tests by the Waterways Experiment Station were carried to 10 cycles, whereas other agencies ran only 5 cycles.

f. Magnesium Sulfate Soundness. Tests were conducted according to parts of ASTM Designation C 88-46T applicable to the magnesium sulfate test. In general, tests by the Waterways Experiment Station were carried
to 10 cycles, whereas other agencies ran only 5 cycles.

7. Freezing and Thawing. Samples consisted of 10 lb of particles passing a 2-in. sieve and retained on a 1-1/2-in. sieve. Some were prepared by jaw crushing, others by hand chipping, as indicated by appropriate notes on Table 1. Samples were immersed in water for 24 hours prior to test and frozen and thawed in an immersed state. One complete cycle of freezing and thawing was accomplished every 2 hours; the test consisted of 100 such cycles. The results reported are per cent loss, which is the per cent of total sample by weight passing a 1-1/2-in. sieve, after 100 cycles of freezing and thawing. The appearance of each of the samples tested, before test, and after sieving upon completion of the test is shown in Figures 21 through 30.

11. Applicability of Tests. In addition to gradation and thickness requirements, a primary requisite of riprap is durability. It should remain in place under the action of waves and not disintegrate under climatic influences. The requirements for durability would necessarily vary with severity of wave action and with the climate, so that no one set of specifications would necessarily govern the quality of riprap rock for all possible installations. A rock for riprap generally should be dense, sound, and not subject to weathering or solution. The usual tests for riprap stone such as unit weight, absorption, abrasion, and soundness, are attempts to evaluate the quality of the rock in an effort to predict satisfactory behavior in the field. Some data are available correlating test results with behavior of rock in the field; these data tend to show that specification limits for the test results are too restrictive and
may be relaxed considerably without permitting unsatisfactory rock for riprap purposes. Until more complete data are available, however, the test results are best used as a guide to indicate potentially poor behavior in the field. One of the best criteria for suitability of riprap rock is a satisfactory service record in similar installations and as a durable building stone. For a more extensive discussion of these factors reference may be made to the Report of the Subcommittee on Slope Protection of the Committee on Earth Dam of the Soil Mechanics and Foundations Division, ASCE, Proceedings, ASCE, June 1943, pp. 845-866 and subsequent discussion thereof.

12. Specification Limits. Agencies which have used riprap protection stone usually establish certain specification limits for various tests which will indicate acceptability of the rock. However, there is no great degree of consistency in specification requirements between different agencies. For example, the following criteria have been used in the Vicksburg and Little Rock Districts, CE, for riprap stone:

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vicksburg</td>
</tr>
<tr>
<td>Unit weight, lb per cu ft</td>
<td>150 min.</td>
</tr>
<tr>
<td>Absorption, per cent</td>
<td>1.5 max.</td>
</tr>
<tr>
<td>Deval abrasion, per cent loss</td>
<td>6.0 max.</td>
</tr>
<tr>
<td>Sulfate soundness, 5 cycles, per cent loss</td>
<td>1.25 max.</td>
</tr>
</tbody>
</table>

It may be seen from the foregoing that there is no great consistency in the tests required nor in the specification limits established. Thus, until behavior data are made available, the use of rigid specification limits may be open to question.
13. **Discussion of Individual Tests.** The use of the tests as indicators, however, has considerable merit and will usually permit the exclusion of obviously unsuitable materials from being used as riprap. Following are a few comments on indications which may be obtained from the results of such tests as are reported herein.

   a. **Unit Weight.** A low unit weight (below 140 to 150 lb/cu ft) usually indicates a light, and possibly porous, rock which may be susceptible to movement under wave action. Heavy unit weights, on the other hand, do not necessarily mean a sound, dense rock, since the mineral composition may influence the weight. For example, an ironstone may be quite heavy, due to the weight of the iron minerals, yet be quite porous.

   b. **Absorption.** An approximate indication of the porosity of a rock is obtained from the absorption test. A relatively high value would indicate appreciable permeable pore space present. Absorption and unit weight values together can usually establish whether a rock is dense or not. A porous rock might be more susceptible to disintegration due to weathering, depending on the severity of the climate; however, data are not available to establish definite limiting values.

   c. **Abrasion Tests.** The abrasion tests might be considered to evaluate the durability of the rocks to grinding one upon another due to wave action (although this condition would not be desirable for the rock as placed in the field) or to abrasion by driftwood, ice, etc. Results of two types of abrasion tests are presented, the Deval and Los Angeles. Where comparative data are available it would appear that the percentage of wear was reported by the Los Angeles test is generally higher, even
for 100 revolutions, than that reported by the Deval test. This factor should be considered in establishing specification limits for abrasion. In general, a high percentage of wear indicated by either test may indicate a rock unsuitable for riprap.

d. Soundness Tests. This type of test attempts to evaluate the effect of weathering action on rock. The mechanical action in the sulfate tests and in the freezing and thawing tests may approximate the action of freezing and thawing water in the pores and fracture planes of the material. Based on these considerations it may be argued that soundness tests are primarily applicable to rock used in regions of severe freezing and would not be so applicable in milder climates. Another consideration is the severity of reaction obtained by the different methods of test. In the tests reported on Table 1, for equal cycles of testing, a generally greater per cent loss was obtained with sodium sulfate than with magnesium sulfate. The freezing-and-thawing test results are not considered comparable to the sulfate-test losses since the percentage of loss was determined upon a different basis. Examination of the photographs (Figures 21 through 30) of the freezing-and-thawing test samples and making visual allowance for those particles passing the 1-1/2-in. sieve which did not appear to have been split by freezing and thawing, there is an indication that 100 cycles of freeze-thaw testing are materially less severe than 10 cycles of the sulfate test. In the sodium sulfate soundness test, limited data are available to indicate that a correlation exists between the test and field behavior, and that a safe limiting value for loss in the laboratory test at 10 cycles is 10 per
cent. It will be noted that data were available on comparison of rock prepared by jaw crushing and hand chipping for the freeze-thaw tests. Examination of the photographs of freezing-and-thawing specimens indicated that, in general, samples that were jaw crushed disintegrated more in the test than did the hand-chipped specimens. This statement is not obvious from examination of the numerical test results but was determined visually by excluding those particles which showed no visible disintegration after test, yet passed through the 1-1/2-in. sieve.

14. Recommendations. With the considerations presented in the preceding paragraphs in mind, the test data on table 1 were reviewed in an effort to determine whether any sources were definitely not acceptable for use as riprap. The various sources are discussed below.

a. Sources with No Test Data. A number of locations are listed on table 1 where no sample was obtained for testing purposes. In general, these have been included in the table for record purposes and, if any of the sources are considered for riprap use, samples should be obtained and tested. A few of the sources not tested were considered not desirable on the basis of field inspection of the quarry. These were Source Numbers 19 and 20, Vinnsfield and Coochie Brake, La., where the limestone rock was highly fractured and also contained gypsum, and Number 21, Harrisonburg, La., where a very soft siltstone was investigated.

b. Sources with Test Data. Of the sources investigated on which test data were available, all except five produced material which appeared to be acceptable for use as riprap, based on the samples which were tested.

In some instances certain individual test values were outside of what
might be considered specification limits, but in general the data indicated the rock would be acceptable for use. Of the five sources mentioned above, two were definitely not acceptable and three were questionable; these sources are discussed in more detail below.

(1) Sources 6 and 7 at Daingerfield and Marietta, Texas.
The material in these sources consisted of ferruginous sandstone called "ironstone". The rock had high absorption values and one sample showed quite high loss in the sodium sulfate test. Other information indicated that the material at Daingerfield was quite variable and that at Marietta had been practically exhausted from the pit. On the basis of high absorption, sulfate loss, and variability of material they are excluded from consideration.

(2) Source 14, Dierks Lumber Company Property near Little Rock, Ark. The unit weight of the sandstone from this source was only 142 lb per cu ft, not an excluding factor, but an indication of a possibly poor rock. The absorption was fairly high (2.62%) but not excessive, and the Durlab abrasion loss was 6%, which is beginning to be high for this test. However, there was little loss in the sulfate test. Field information indicates the rock to be quite variable in hardness and grain size. The test data do not indicate that the rock should be excluded for use as riprap; however, only surface samples were tested, and experience in the area tends to show that the sandstone may be considerably softer back from exposed faces. Further testing is recommended if the source is considered for possible use as riprap.

(3) Source 39, Grenada Dam, Miss. The rock occurs principally as boulders of sandstone and not in any great quantity as ledge
rock. This is also a ferruginous sandstone with high absorption and high loss on the Deval abrasion. The loss in the sodium sulfate test was fairly high but not considered excessive. The test data indicate a rock which may be satisfactory for riprap; however, in this case also further testing is recommended if this source is considered for use.

(4) **Source 40, near the Vicksburg Bridge, Miss.** This material is a limestone which had a low unit weight, high absorption, very high abrasion loss, and disintegrated in the magnesium sulfate tests. The tests were made on the more resistant rock found at this location, and careful selection would be necessary to obtain large quantities for riprap. Although the test results indicate a very poor material, it is noted that an island of similar rock nearby has withstood river action for many years. Therefore, it may be acceptable for certain types of revetment work if found in sufficient quantity, but may not be desirable for riprap on important structures. A more detailed discussion of this source is contained in the Memorandum for the President, "Mississippi River Commission, dated 5 October 1948, from the Waterways Experiment Station, subject: "Examination of Limestone Exposed Near the Vicksburg Bridge".

15. **Summary.** A survey has been made of the Lower Mississippi Valley Division and adjoining areas to locate sources of riprap materials. A total of 43 sources have been located, material in five of these sources is regarded as unsuitable, and that in three others as questionable for use as riprap. Sources of apparently satisfactory material were located in Oklahoma, Texas, Arkansas, Missouri, Kentucky, Tennessee, and Alabama in or near the Lower Mississippi Valley Division.
<table>
<thead>
<tr>
<th>No.</th>
<th>Owner or Operator</th>
<th>Location of Quarry or Pit</th>
<th>Type of Rock</th>
<th>Number of Samples</th>
<th>Unit Weight As Per Cu Ft</th>
<th>Absorption Per Cu Ft</th>
<th>Ab. Per Cu Ft</th>
<th>Abrasion Test</th>
<th>No.</th>
<th>Duration of Tests</th>
<th>Magnetic Attrition</th>
<th>Weight ofLoss</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baptist Stone Co.,</td>
<td>5 mi S of Davis, Okla.</td>
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**Table 1**

**Summary of Tests on Riprap Materials**

**NOTES:**
5 Grading 'A' used. 6 Grading 'D' used. 6 Grading 'C' used. 6 Sample hand chipped.

(Continued on next page)
Table 1 (Continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Owner or Operator</th>
<th>Location of Quarry or Pit</th>
<th>Type of Rock</th>
<th>Number of Samples Tested</th>
<th>Unit Weight Absorption</th>
<th>Absorption Tests</th>
<th>Los Angeles Coding Grading</th>
<th>Soundness Tests</th>
<th>Compressive Strength</th>
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<tr>
<td>27</td>
<td>Federal Materials Co.</td>
<td>Cape Girardeau, Mo.</td>
<td>Flat Rock Limestone</td>
<td>2</td>
<td>160</td>
<td>169</td>
<td>0.3</td>
<td>2.6</td>
<td>2.5</td>
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<tr>
<td>28</td>
<td>E. C. Schroeder Co.</td>
<td>Ely, Ky.</td>
<td>Limestone (Cherty)</td>
<td>6</td>
<td>160-165</td>
<td>165</td>
<td>0.2-0.7</td>
<td>0.4</td>
<td>2.7-3.2</td>
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<tr>
<td>29</td>
<td>Carolina Stone Co.,</td>
<td>Carbisle, Ky.</td>
<td>Limestone</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
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<tr>
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<td>Murphy Bros.,</td>
<td>Bowling Green, Ky.</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
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<td>33</td>
<td>Franklins Lime Co.,</td>
<td>Densley Quarry near Nashville, Tenn.</td>
<td>Limestone</td>
<td>9</td>
<td>162-172</td>
<td>169</td>
<td>0.1-1.2</td>
<td>0.3</td>
<td>2.7-4.5</td>
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<td>34</td>
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<td>Erwin, Tenn.</td>
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<td>No sample obtained</td>
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<td>165</td>
<td>0.3-1.0</td>
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<td>4.5-5.2</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
<td>No sample obtained</td>
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<tr>
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<td>No sample obtained</td>
<td>No sample obtained</td>
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<td>38</td>
<td>Owenne Co.,</td>
<td>Groves Dam, Miss.</td>
<td>Ferruginous Sandstone</td>
<td>3</td>
<td>140-165</td>
<td>152</td>
<td>5.3-6.6</td>
<td>2.2</td>
<td>5.6-7.4</td>
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<td>Bowers Limestone</td>
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<td>130-131</td>
<td>136</td>
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<td>No sample obtained</td>
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<tr>
<td>42</td>
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<td>3 mi S of Infalla, Ala.</td>
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<td>No sample obtained</td>
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<td>No sample obtained</td>
<td>No sample obtained</td>
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<td>0.2-0.7</td>
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<td>2.7-3.2</td>
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Notes: * Grading 'A' used. 6 Sample jaw crushed. * Grading 'B' used. 6 Sample hand chipped.
TABLE 1 A

**Additional Data - Los Angeles Abrasion Test**

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<th>Source No.</th>
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<td></td>
<td>100 Rev 500 Rev 500 Rev</td>
<td>500 Rev</td>
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<tr>
<td>2</td>
<td>Big Canyon limestone</td>
<td>11.6 29.6</td>
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<td>3</td>
<td>Ryder dolomite</td>
<td>6.7 29.7</td>
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<td>7.9 30.7</td>
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<td></td>
<td>Dark gray syenite</td>
<td>5.6 20.9</td>
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*Grading A* 25.7  
*Grading B* 23.5 (North face)  
31.9 (South face)  
42.3  
24.7  
25.3 (Upper zone)
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<td>Recent 30, Pleistocene or Glacial Age 970</td>
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<td></td>
<td>Tertiary 54,000</td>
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<tr>
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<td>Cretaceous 65,000</td>
<td>Gulf 40,000, Comanchean 25,000</td>
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<tr>
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<td>KEEWATIN</td>
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**Table 2**
VERT. SCALE: 1 INCH = 1200 FEET

SECTION SOUTHEAST OF THE CAHABA COAL FIELD IN ALABAMA SHOWING THE WARSAW AND NEWALA LIMESTONES.
VERT. SCALE: 1 INCH = 1200 FEET

SECTION NORTHWEST OF THE CAHABA COAL FIELD IN ALABAMA SHOWING THE BANGOR AND CHICKAMAUGA LIMESTONES.
These bedded rocks, originally laid down as nearly horizontal layer of mud and sand under the sea, were folded into a high mountain range about the time the Appalachian Mountains were formed. This was worn down by streams and buried beneath later sediments, which have been stripped away by erosion, exposing the roots of the old mountains.
SECTION IN OZARK REGION OF ARKANSAS SHOWING DOLOMITES AND LIMESTONES.
<table>
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<th>Time Period</th>
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<th>Cent. Mo.</th>
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<td>Callaway</td>
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<td>St. Laurent</td>
<td>Beauvais</td>
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<tr>
<td></td>
<td>Grand Tower</td>
<td>Mineola-Cooper</td>
</tr>
<tr>
<td>Lower Series</td>
<td>Little Saline</td>
<td>Clear Creek</td>
</tr>
<tr>
<td></td>
<td>Bailey</td>
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</tr>
<tr>
<td>Niagara Group</td>
<td>Maquoketa-Thebes</td>
<td>Fernvale</td>
</tr>
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<td>Alexandriaian Series</td>
<td>Kimmswick</td>
<td>Decorah Platte</td>
</tr>
<tr>
<td>Lower Series</td>
<td>Joachim Dutchtown</td>
<td>St. Peter Everton</td>
</tr>
<tr>
<td>Upper Series</td>
<td>Ojic</td>
<td>Smithville Powell Cotter Jefferson City</td>
</tr>
<tr>
<td></td>
<td>St. Peter Everton</td>
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<tr>
<td>Lower Series</td>
<td>Or</td>
<td>Roubidoux</td>
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<td></td>
<td>Gasconade Van Buren Gunter ss.</td>
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SECTION IN OUACHITA REGION OF ARKANSAS SHOWING THICK SHALES AND SANDSTONES.

FIGURE 6
**SECTION IN KENTUCKY EAST OF THE TENNESSEE RIVER**
**SHOWING CHERTY LIMESTONES OF THE MISSISSIPPAN.**
QUARTZITIC SANDSTONE
JACKFORK, MISSISSIPPIAN

BIG ROCK STONE & MATERIAL CO.
NORTH LITTLE ROCK, ARK.
BIG CANYON QUARRY
10 MILES SOUTH OF DAVIS, MURRAY CO., OKLA.

WEST

ARKBUCKLE LIMESTONE
LOWER AND MIDDLE ORDOVICIAN

40° DIP

±90 FT

±800 FT

EAST

2 FT SHALE BED

LIMESTONE IS MEDIUM GRAY IN COLOR, VERY DENSE, ALMOST LITHOGRAPHIC. IT IS MASSIVE BEDDED WITH FEW VERY THIN SHALE PARTINGS. IN PLACES, CALCITE FILLS VEINS AND FRACTURES. FAINT JOINTING IS NORMAL TO BEDDING. THE FORMATION DIPS ABOUT 40° WEST.

O SAMPLE LOCATION

DOLESE BROS.
OKLAHOMA CITY, OKLA.
PLANT AT RYDER STATION, NEAR TROY.
MURRAY CO., OKLA.
QUARRY 3 MILES WEST

EAST

WEST

HEIGHT AND DISTANCE ESTIMATED

1 ON 5 SLOPE

\[ \pm 20 \text{ FT} \]

\[ \pm 250 \text{ FT} \]

ELEVATION

THIS IS AN OUTLIER OF THE ROYER DOLOMITIC MARBLE OF UPPER CAMBRIAN AGE ON GRANITE.

THE DOLOMITE IS LIGHT GRAY, ALMOST WHITISH IN COLOR. IT IS QUITE CRYSTALLINE AND CONTAINS A FEW VOIDS AND THIN SHALE BREAKS. THE BEDDING IS MASSIVE AND LIES ABOUT HORIZONTAL. THERE ARE TWO SETS OF VERTICAL JOINT SYSTEMS.

O SAMPLE LOCATION

ROCK PRODUCTS CO.
ADA, OKLA.

FIGURE 10
BROMIDE QUARRY
VICINITY BROMIDE, JOHNSTON CO., OKLA.

SOUTH

VIOLA LIMESTONE
MIDDLE & UPPER ORDOVICIAN

THE STONE IS LIGHT BUFF GRAY TO LIGHT GRAY
IN COLOR, MASSIVE BEDDED AND DENSE. IN PLACES
CALCITE FILLS VEINS AND FRACTURES. THERE ARE
TWO VERTICAL JOINT SYSTEMS.

NORTH

SAMPLE LOCATIONS

DOLESE BROTHERS
OKLAHOMA CITY, OKLA.

+ 2000 FEET
ELEVATION

198 FT.
BIG ROCK STONE & MATERIAL CO.
OLD SYENITE QUARRY
2.5 MILES SOUTH OF LITTLE ROCK, ARK.
SYENITE QUARRY 2.5 MILES SOUTH OF LITTLE ROCK, ARK.
SEC. 29, T 3 S, R 17 W, HOT SPRING CO., ARKANSAS

LOCATION OF SAMPLES NOT TO SCALE
ALL DISTANCES ARE APPROX.

ROCK IS NEPHELINE SYENITE

ROCK ISLAND R.R.
PROPOSED QUARRY SITE
3½ MILES SOUTH OF EDDYVILLE, KENTUCKY
ON STATE HWY 95

THE LIMESTONE IS IN THE MERAMEC GROUP OF THE IOWA SERIES,
LOWER MISSISSIPPAN.

IT VARIES FROM MEDIUM TO DARK GRAY IN COLOR, IS QUITE
DENSE, MASSIVE, AND HORIZONTALLY BEDDED. IT CARRIES
VARYING AMOUNTS OF CHERT.

OPERATOR HAS CONTRACT FOR RIPRAPH, GRENADA DAM.

O SAMPLE LOCATION

E.C. SCHROEDER CO.
ISBELL, ALA.
CARTERS LIMESTONE, (BLACK RIVER) ORDOVICIAN
IT IS LIGHT GRAY IN COLOR, VERY FINELY CRYSTALLINE
AND MASSIVE BEDDED BUT BREAKS ALONG HORIZONTAL
BEDDING PLANES. FAINT VERTICAL JOINT SYSTEMS
ARE PRESENT.

FRANKLIN LIMESTONE CO.
NASHVILLE, TENN.
OPERATOR HAS CONTRACT FOR RIPRAP, ENID DAM.
QUARRY SITE
3 MILES SOUTH OF COLUMBIA, TENN.
ON STATE HWY 64

HEIGHTS AND DISTANCES ESTIMATED ON 2/12/48

TOP OF ROCK ± 30 FT

± 550 FT

ELEVATION

THIS IS THE CARTERS LIMESTONE, ORDOVICIAN IN AGE AND CORRELATES WITH THE CHICAGUAMA LIMESTONE OF ALABAMA.

IT IS LIGHT GRAY IN COLOR, DENSE, EVEN BEDDED IN BEDS TWO OR MORE FEET THICK. SOME CHERT IS PRESENT IN THE LOWER BEDS WHICH WILL NOT BE QUARRIED.

OPERATOR HAS CONTRACT FOR RIPRAP, ENID DAM.

FRANKLIN LIMESTONE CO.
NASHVILLE, TENN.
SAWED ETCHED SURFACE, X 2. THE LIGHT PATCHES ARE DOLOMITIC REPLACEMENTS, AND THE SMALL DARK SPECKS, CARBONACEOUS MATERIAL. STYLOLITES ARE INDICATED BY (A).

LIMESTONE FROM DANLEY QUARRY, DANLEY SIDING, NEAR NASHVILLE, TENN. (VICKS-3 G-1)
CARTERS LIMESTONE
UPPER ORDOVICIAN
COLUMBIA, TENN.
SAWED ETCHED SURFACE, NATURAL SIZE. THE LIGHTetest AREAS ARE DOLOMITISED. STYLOLITES ARE INDICATED BY (A).

LIMESTONE FROM COLUMBIA QUARRY, COLUMBIA, TENN. (VICKS-3G-2)

FIGURE 17B
ISBELL QUARRY
0.3 MILE SOUTH OF ISBELL, ALA.

BANGOR LIMESTONE
LOWER CHESTER, UPPER MISSISSIPPIAN

LIMESTONE IS MOTTLED GRAY IN COLOR, VERY FINELY CRYSTALLINE AND MASSIVE BEDDED. CALCITE FILLS THIN VEINS AND FRACTURES AND OCCURS AS FLECKS. FORMATION IS ABOUT HORIZONTAL.

OPERATOR HAS CONTRACT FOR RIPRAP, GRENADA DAM

O SAMPLE LOCATION

E. SCHROEDER CO.
ISBELL, ALA.
BANGOR LIMESTONE, LOWER CHESTER, UPPER MISSISSIPPIAN

LIMESTONE IS MOTTLED GRAY IN COLOR, VERY FINELY CRYSTALLINE AND MASSIVE BEDDED. CALCITE FILLS THIN VEINS AND FRACTURES AND OCCURS AS FLECKS. FORMATION IS ABOUT HORIZONTAL.

E.C. SCHROEDER CO.
ISBELL, ALA.

OPERATOR HAS CONTRACT FOR RIPRAP, GRENADE DAM.
BANGOR LIMESTONE
UPPER MISSISSIPPION

E. C. SCHROEDER CO.
ISBELL, ALA.
COBB CITY QUARRY
8 MILES SOUTHEAST OF GADSDEN, ALA.

OPERATING THREE FACE, THE 40 FT, THE 50 FT, AND THE HIGH FACE.

CHICAGUAMA LIMESTONE (BLACK RIVER), ORDOVICIAN
LIGHT TO DARK GRAY IN COLOR, VERY MASSIVE BEDDED, BUT SHOWS SOME STRATIFICATION. HAS TWO JOINT SYSTEMS NORMAL TO BEDDING. THE FORMATION DIPS ABOUT 45° SOUTHEAST.

ALABAMA AGGREGATE CO.
BIRMINGHAM, ALA.
PELHAM QUARRY
12 MILES SOUTHEAST OF BIRMINGHAM, ALA.

32 - 35 FT FACE

THIS FACE WILL NOT BE QUARRIED

± 50° DIP SOUTHEAST

BOTTOM OF QUARRY FLOOR FAIRLY FLAT

± 600 FT

NARROW 2 - 3 FT ZONE
DOLOMITIC, COARSER GRAINED STONE

3 FT OVERBURDEN

NEWALA LIMESTONE
(BEEKMANTOWN), ORDOVICIAN

ROCK IS LIGHT TO MEDIUM GRAY. VERY DENSE LIMESTONE IN BEDS TO THREE FEET. JOINTING IS NORMAL TO BEDDING WHICH IS ABOUT HORIZONTAL. THE FORMATION DIPS ABOUT 50° SOUTHEAST.

O SAMPLE LOCATION

ALABAMA AGGREGATE CO.
BIRMINGHAM, ALA.

FIGURE 20
FREEZING AND THAWING TEST - RIPRAP MATERIALS

JAW-CRUSHED LIGHT COLORED SYENITE, BIG ROCK STONE CO., SOUTH OF LITTLE ROCK, ARK. (TUL-1 G-24(2) A, FPL 2124 A & B)

HAND-CHIPPED LIGHT COLORED SYENITE, BIG ROCK STONE CO., SOUTH OF LITTLE ROCK, ARK. (TUL-1 G-24(4) A, FPL 2124 A & B)
FREEZING AND THAWING TEST—RIPRAP MATERIALS

BEFORE TEST
100% RETAINED ON 1 1/2"

AFTER 100 CYCLES F & T
0.8% PASSING 1 1/2"

JAW-CRUSHED DARK COLORED SYENITE, BIG ROCK STONE CO., SOUTH OF LITTLE ROCK, ARK. (TUL-1 G-24 (2) B, FPL 2122 A)

BEFORE TEST
100% RETAINED ON 1 1/2"

AFTER 100 CYCLES F & T
1.2% PASSING 1 1/2"

JAW-CRUSHED DARK COLORED SYENITE, BIG ROCK STONE CO., SOUTH OF LITTLE ROCK, ARK. (TUL-1 G-24 (2) C, FPL 2122 B)
FREEZING AND THAWING TEST - RIPRAP MATERIALS

BEFORE TEST
100% RETAINED ON 1/2"

AFTER 100 CYCLES F & T
2.4% PASSING 1/2"

HAND-CHIPPED DARK COLORED SYENITE, BIG ROCK STONE CO., SOUTH OF LITTLE ROCK, ARK. (TUL-1G-24(3), FPL 2122 A & B)
FREEZING AND THAWING TEST—RIPRAP MATERIALS

BEFORE TEST
100% RETAINED ON 1/2"
JAW-CRUSHED LIMESTONE, DOLESE BROS., BIG CANYON QUARRY NEAR DOUGHERTY, OKLA.
(LMVD-G1 FPL 2108 A&B)

AFTER 100 CYCLES F & T
48.0% PASSING 1/2"

BEFORE TEST
100% RETAINED ON 1/2"
HAND-CRIPPED LIMESTONE, DOLESE BROS., BIG CANYON QUARRY NEAR DOUGHERTY, OKLA.
(LMVD G-(2)FPL 2108 A&B)

AFTER 100 CYCLES F & T
3.6% PASSING 1/2"
BEFORE TEST
100% RETAINED ON 1 1/2"

AFTER 100 CYCLES F & T
1.6% PASSING 1 1/2"

JAW-CRUSHED LIMESTONE (NORTH FACE), ROCK PRODUCTS MFG. CO.,
RYDER STATION NEAR TROY, OKLA. (LMVD G-2A, FPL 2107 B)

FREEZING AND THAWING TEST - RIPRAP MATERIALS
FREEZING AND THAWING TEST - RIPRAP MATERIALS

BEFORE TEST
100% RETAINED ON 1 1/2"

AFTER 100 CYCLES F & T
5.8% PASSING 1 1/2"

HAND-CHIPPED LIMESTONE, ROCK PRODUCTS MFG. CO., RYDER STATION
NEAR TROY, OKLA. (LMVD 6-2 (2), FPL 2107 A & B)
AFTER 100 CYCLES F & T
0.4 % PASSING 1 1/2"

JAW-CRUSHED DOLOMITE, DOLESE BROS., BROMIDE, OKLA. (LMVD G-3(2)FPL 2106 A&B)

BEFORE TEST
100 % RETAINED ON 1 1/2"

FREEZING AND THAWING TEST - RIPRAP MATERIALS

BEFORE TEST
100 % RETAINED ON 1 1/2"

HAND-CHIPPED DOLOMITE, DOLESE BROS., BROMIDE, OKLA. (LMVD G-3(2)FPL 2106 A&B)

AFTER 100 CYCLES F & T
4.5 % PASSING 1 1/2"
Freezing and Thawing Test - Riprap Materials

Before Test
100% retained on 1/2"
Hand-chipped Novaculite, Coogan Gravel Co., Butterfield, Ark.
(LMVD G-4(2), FPL 2078+2125A)

After 100 Cycles F & T
12.0% passing 1/2"
(LMVD G-4(2), FPL 2077+2125A)
HAND-CHIPPED LIMESTONE, ALABAMA AGGREGATE CO., PELHAM, ALA.

FREEZING AND THAWING TEST - RIPRAP MATERIALS
FREEZING AND THAWING TEST - RIPRAP MATERIALS

BEFORE TEST
100% RETAINED ON 1 1/2"

AFTER 100 CYCLES F & T
3.8% PASSING 1 1/2"

JAW-CRUSHED LIMESTONE, FRANKLIN LIMESTONE CO., COLUMBIA, TENN. (VICKS-3G-2)