SA(IR)-227

DIRECTORATE GENERAL OF MINERAL RESOURCES

MINISTRY OF PETROLEUM AND MINERAL RESOURCES
JIDDAH, SAUDI ARABIA

AGGREGATE RESOURCES OF THE ABHA-KHAMIS MUSHAYT AREA A PRELIMINARY REPORT

KINGDOM OF SAUDI ARABIA

By Lawrence F. Rooney and Ziad H. Al-Koulak

SAUDI ARABIAN PROJECT REPORT 227
1978

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

U. S. GEOLOGICAL SURVEY [Reports - Open file series]

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ABSTRACT

The area within 30 km of Abha and Khamis Mushayt in the Asir province of the Kingdom of Saudi Arabia is experiencing rapid growth and a corresponding strong demand for construction materials, including aggregate. The major source of aggregate at present is wadi gravels, supplemented by shallow pits in bedrock. A vast quantity of coarse aggregate as yet untouched is readily available near Abha and Khamis Mushayt in the granite, gabbro, and gneiss bedrock that underlie the area. Fine aggregate of high quality is readily available in the major wadis.

INTRODUCTION

Abha and Khamis Mushayt are two of the four cities in the southwestern part of the Kingdom experiencing the greatest growth (the other two are Najran and Jizan). Abha is the capital of the Asir Emirate, and Khamis Mushayt, 25 km northeast, is an agricultural, military, and transportation center. Business establishments, public buildings, and residences are being constructed along the highway joining the two cities so that in time they will become effectively one metropolitan area.

The Abha-Khamis Mushayt area is arbitrarily defined as that bounded by longitudes 42°20'E. and 43°E. and latitudes

18°N. and 18°30'N. (fig. 1), which corresponds roughly to an area within 30 km of the Abha-Khamis Mushayt axis, the maximum distance we expect aggregate to be transported in competition with existing supplies. The area's population, rapidly growing, is estimated between 100,000 and 125,000.

No previous work has been published on the aggregate resources of the Abha-Khamis Mushayt area. Most of the area, however, falls within the Khamis Mushayt 30-minute quadrangle mapped by Coleman (1973). The remainder falls within the Jabal Sawdah 30-minute quadrangle mapped by Ratte and Andreasen (1974).

The geologic boundaries shown on the accompanying figure are taken from Coleman's and Ratte and Andreasen's reports. In order to reconcile the two maps along their common boundary, Ratte and Andreasen's Hali Group was equated with a unit mapped by Coleman as young metamorphic rocks and, in the northwest corner of figure 1, part of Ratte and Andreasen's Hali Group was equated with Coleman's Khamis Mushayt Gneiss.

Since the 30-minute quadrangle mapping was completed, many kilometers of roads have been paved. No new aerial photography is available, however, and the location on figure 1 of these paved roads and the new airport is only roughly approximate. The newly paved road that runs southeast from Abha and connects with the paved road that runs south from the Khamis Mushayt-Najran road near Jabal

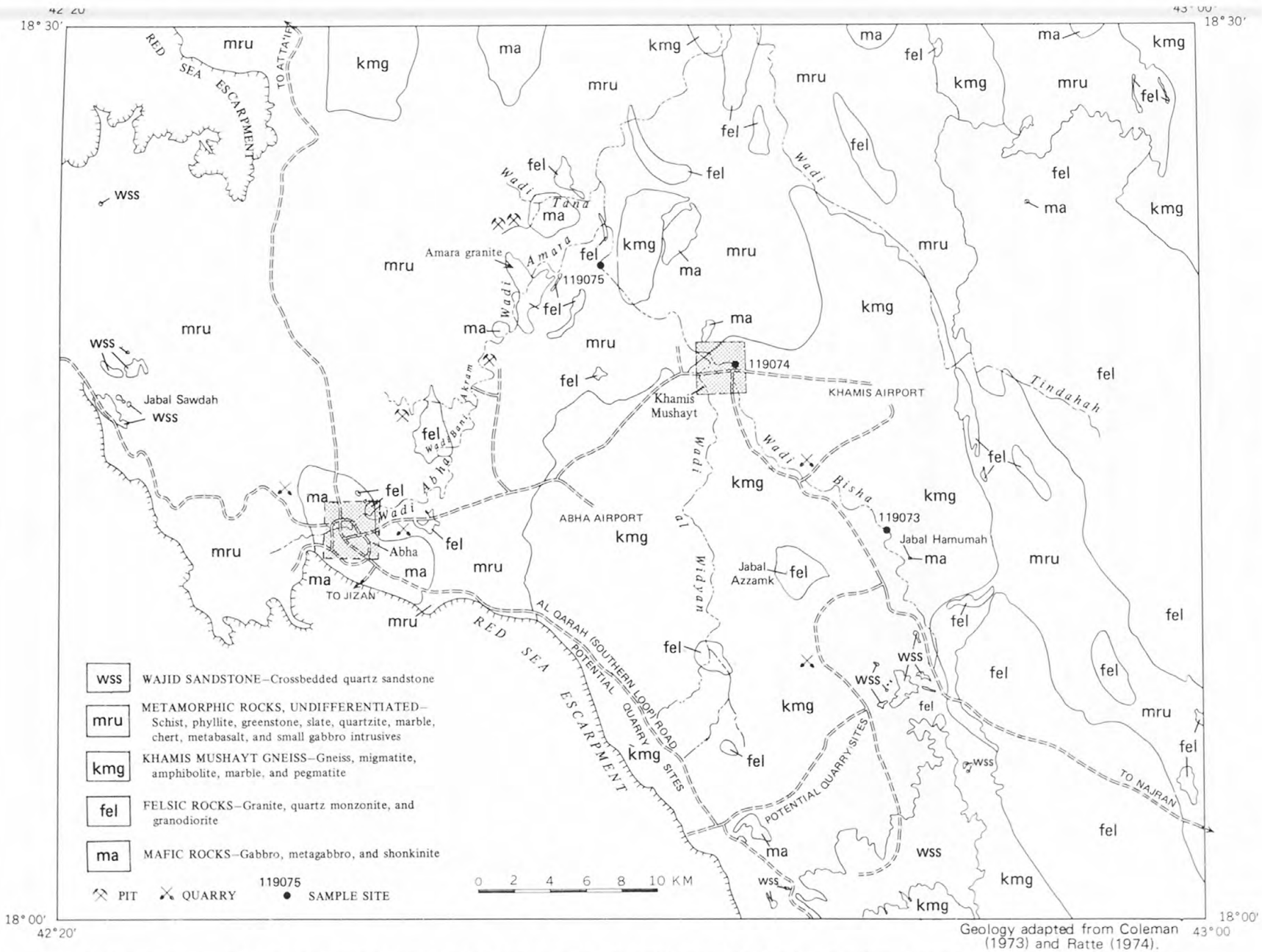

Figure 1.- Reconnaissance geologic map of the Abha-Khamis Mushayt area showing potential sources of aggregate and producing areas.

Azzamk, the full length of which we call the southern loop road, is a major improvement in the area's transportation network.

This report results from work done by the U.S. Geological Survey in accordance with its Work Agreement with the Saudi Arabian Ministry of Petroleum and Mineral Resources.

DEMAND FOR AGGREGATE

The need for aggregate in the Abha-Khamis Mushayt area results from general accelerated construction, including a large number of public buildings and residences, but especially from the paving of landing strips and roads. A large civilian airport is being constructed between Abha and Khamis Mushayt (fig. 1). Work continues on the military airport and the military post near Khamis Mushayt. The highway that leads down the escarpment towards Jizan is under contruction. The highway between Abha and Khamis Mushayt is being widened to four lanes. The highway from Khamis Mushayt to Najran is being widened as far as the southern loop road. Other secondary roads and streets are being paved or being prepared for paving. One aggregate producer reports that approximately 120 km of farm-to-market roads will be paved in the next few years. All streets, highways, and runways will need periodic maintenance.

The nearly ideal weather and spectacular scenery of the area offer much potential for tourism. At an elevation of approximately 2000 m, Abha and Khamis Mushayt have cool

nights, even in the summer, and, at a latitude of 18°N., their days are pleasantly warm during the winter. The scenic highway between Taif and Abha is practically completed. The last section of the Jizan-Abha highway also is near completion, and the civilian airport will probably be ready in 1977. The combination of weather, easy access, and scenery, coupled with the Kingdom's rapidly rising standard of living, makes a boom in the construction of hotels and summer villas virtually certain. It is reported that more than 5 billion riyals have been allocated to develop the Jabal Sawdah region into a recreation area.

PRESENT PRODUCTION

From wadis

Because of its current rapid growth, the Abha-Khamis Mushayt area is dotted with numerous aggregate mines and asphalt-mix plants. Most mines are using wadi material and seem to be of an ad hoc, temporary nature. The typical mine is a shallow pit along the major wadi (locally called Wadi Abha, Wadi Bani Akram, or Wadi Amara, fig. 1) west of the Abha-Khamis Mushayt highway. Front-end loaders, avoiding the large boulders, scoop up wadi sand and gravel, which is loaded into trucks and transported to a nearby small plant. At least one plant has a primary jaw crusher but most have only secondary crushers. Some have only screens. In plants with crushers, the material above a selected diameter, for example 1 1/2 inches[1/], is crushed, and all material is

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[1/] Sieve sizes are quoted by operators in inches. Other measurements are metric.

screened to the sizes demanded by the market. The material is then trucked to asphalt plants or job sites. It is not washed.

The sand and gravel deposits of the Abha-Khamis Mushayt area have the same advantages that sand and gravel deposits share everywhere, most importantly low cost. They are easily mined, and nature has done most of the crushing. Unlike many sand and gravel deposits elsewhere in the world, however, the wadi deposits are thin (average thickness of gravel is reported to be about 1 1/2 m) and, without replenishment, would rapidly be exhausted. According to the operators of the two largest plants, the life of the pits may be prolonged indefinitely by occasional flooding, which renews the supply. The shallow water table (less than 3 m) complicates mining in the few areas where gravel is several meters thick.

Random samples were collected from stockpiles of coarse gravel (a mixture of crushed and uncrushed, about 2 to 4 cm diameter) at several aggregate plants and pits. More than 50 percent of the aggregate is gabbroic or doleritic rock. The remainder is mainly gneiss and other durable metamorphic rocks with only ten percent or less of granite. One aggregate producer reports that the specific gravity of this material compacted to 6 percent porosity is 2.41.

A rough estimate of current production in the Abha-Khamis Mushayt area is 250,000 cubic meters of aggregate per year. Demand is expected to increase. An operator of one of the largest plants observed that, given one more year without

floods, the gravel supply in the region would be inadequate to meet current needs. The last flood was in 1973.

A disadvantage of using wadi material is the high proportion (40 to 60 percent) of sand and fines produced at some locations. Likewise, the quantity of a product of any size depends largely upon the size distribution of the wadi material. The lithology, and therefore the quality and physical characteristics of the aggregate, also is less subject to control in gravel than it would be in a primary quarry.

From bedrock

Cost of quarrying or unwillingness to use explosives rather than quality of aggregate has apparently governed quarry operations. Also quarries, like sand and gravel pits, appear to be of an ad hoc nature, designed for a few year's rather than for decades' operation at one location.

The few quarries in the Abha-Khamis Mushayt area are located in highly fractured rock near the surface. Bulldozers and front-end loaders doze or scoop out the weathered rock to as much as 10 m depth and push or carry it to a crusher. The harder, more resistant rock (and better aggregate) is in some instances left as sheer vertical faces on either side of the quarry.

In general, portable equipment is used and buildings and massive fixed equipment, such as are found in most quarries elsewhere, are not used.

POTENTIAL AGGREGATE SOURCES

From wadis

Wadi Abha-Bani Akram-Amara and, to a lesser degree, its tributaries, appears to be the most suitable wadi for coarse aggregate. The length along which pits could be developed is about 30 km.

Wadi Basha, Wadi Tindaha, and Wadi Al Widyan, which are larger than Wadi Abha-Bani Akram-Amara, carry mostly sand. Where excavated during bridge construction in Khamis Mushayt, the sand in Wadi Basha was reported to be 10 m thick and to overlie bedrock. In shallow pits, where samples 119073, 119074, and 119075 (fig. 1) were collected, the water table in January, 1977 was at a depth of 1 m. Assuming that production would come from wet pits, low-clay fine aggregate (see table 1) would appear to be abundant.

There are a number of disadvantages in total reliance on wadi material for coarse aggregate, however. Possibly the most serious, but the one we can least appraise at this moment, is long-term supply. Insofar as we know, no one has studied the effect of flooding on gravel supply. Intuitively, however, we surmise that a single flood would add little to the total amount of coarse aggregate; rather, it would redistribute the aggregate remaining in the wadis. Beyond this consideration, we should note that, assuming an average wadi width of 50 m, gravel thickness of 1 1/2 m, and complete excavation, 3.3 km of wadi would be needed to supply 250,000 cubic meters of sand and gravel. In practice, probably more would be required.

Table 1.--Size distribution of upper 1 m of sand and gravel from Wadi Bisha near Khamis Mushayt

Sieve size opening per sq in	Percent retained on sieve 119073	119074	119075
5	1.8	9.1	8.2
10	3.3	16.2	16.5
30	64.5	51.5	40.2
60	27.2	20.6	29.6
100	2.4	1.8	4.2
200	0.6	0.5	1.1
-200	0.2	0.1	0.2

From bedrock

Bedrock in the Abha-Khamis Mushayt area consists dominantly of gneiss and schist with lesser amounts of other rock types, notably igneous rocks of felsic (granite) and mafic (gabbro) composition[2/]. Opinions among aggregate producers as to the amount of bedrock that could be used as aggregate range from zero to virtually infinity.

Apprehension among some producers with regard to the use of bedrock as aggregate appears to stem from three factors: (1) the surface rock is highly weathered and friable, (2) part of the rock contains a large percentage of mica, and (3) most importantly, unweathered bedrock would require blasting.

2/ Felsic igneous rocks have a higher percentage of SiO_2 than mafic igneous rocks. Felsic rocks are light colored and mafic rocks are dark colored. These two broad types of igneous rocks, as well as those intermediate between them, are classified by geologists in considerable detail according to their mineral composition and grain size and are given specific names such as diorite and quartz monzonite. Although some of these rock names are of interest to the geologist and are used in this report, they can be ignored by the general reader.

Felsic (light colored) rocks

Large intrusions of granite, granodiorite, quartz monzonite and other felsic rocks are potential sources of crushed rock in the Abha-Khamis Mushayt area. Because of their surface expression as large weathered boulders, they present a forbidding aspect to quarrying and have not been used heretofore. Explosives would be required.

The most suitable bodies of rock are those having the least weathering, the finest grain size, and the least jointing.

The body of quartz monzonite located about 10 km northwest of the Abha-Khamis Mushayt highway (for identification purposes, called here the Amara granite) is favorably situated with regard to markets. It is only moderately weathered and, although cut by a few basalt dikes, is very homogeneous. The grain size averages 1 to 2 mm. Jointing might reduce blasting efficiency, because in the areas where we examined it approximately 40 percent of the body appears to be jointed into blocks of less than one cubic meter. Many of the joints, however, show little separation and may disappear at shallow depth. The quarryable reserves are estimated at more than 100 million cubic meters.

Other granitic bodies, though quarryable, do not exhibit as many favorable characteristics. The large, banana-shaped quartz monzonite body located about 14 km northwest of Khamis Mushayt has a gneissic texture, is more coarse grained, and is more deeply weathered than the Amara granite. It is also farther from the market center.

The granite body just 7 km northwest of Abha is favorably located but, rather than being a massive body, it is a cluster of intersecting dikes that would be difficult to quarry separately.

The granite body that forms the prominent landmark Jabal Azzamk 11 km southeast of Khamis Mushayt is more highly weathered than the Amara granite and also has a gneissic texture and contains bands of mica that are undesirable in aggregate. However, this body was not examined in detail; its location near the military base makes it difficult to study, and it is unlikely to become a quarry site.

The easternmost part of the study area contains vast expanses of quarryable quartz monzonite and quartz diorite. These deposits are much farther from the market center than those discussed above but are easily accessible from the Najran highway.

Mafic (dark colored) rocks

In the Abha-Khamis Mushayt area, mafic rocks such as gabbro and metagabbro do not form such massive bodies as the felsic rocks but widely scattered occurrences are large enough to support a quarry. Two quarries near Abha are operating in gabbroic rocks within the area mapped as metamorphic rock, undifferentiated (fig. 1). As is typical in the Abha-Khamis Mushayt area, the rock is being bulldozed, not blasted.

Other bodies of gabbroic rock within the undifferentiated metamorphic rocks could be developed. One prime location is a ridge that crosses the southern loop road 2 km southeast of its junction with the highway to Jizan (fig. 1).

A deposit of shonkinite forms the landmark Jabal Humumah (fig. 1). It is small and is estimated to contain only about 1 1/2 million cubic meters to a depth of 50 m below its base, but nevertheless it would be a well-located source of high-quality aggregate. It is only 2 km from the Najran highway, and 15 km from Khamis Mushayt.

Khamis Mushayt Gneiss

The Khamis Mushayt Gneiss is made up of gneiss, migmatite, amphibolite, marble, and pegmatite, which have not been mapped separately (Coleman, 1973). Gneiss appears to be most common.

The gneiss forms both low rounded hills and underlies the weathered debris between the hills. Quarries in the gneiss have been opened in the topographically low areas between outcrops where the gneiss is weathered and easily broken. Along highway cuts where large boulders have been blasted, the gneiss is hard, fresh, and suitable for aggregate. Some gneiss, however, contains thick bands of biotite. Large bodies of granite gneiss suitable for quarrying are found along the southern loop road.

Metamorphic rocks, undifferentiated

The area mapped as Metamorphic rocks, undifferentiated is composed dominantly of schists. Platy and micaceous, they do not make aggregate of high quality. Other rock types, such as marble and other weakly metamorphosed sedimentary rocks, are included in this group. Although no deposits suitable for high-quality aggregate have been noted, a thorough search might reveal thick units of marble, quartzite, or other

suitable rock. As discussed under mafic rocks, gabbroic rocks within the metamorphic rocks are potential sources for aggregate of acceptable quality.

Wajid Sandstone

Because it is soft and highly porous, the Wajid Sandstone, which crops out in nearly horizontal layers along the margins of the map area, is considered unsuitable for aggregate.

CONCLUSION AND RECOMMENDATION

Although aggregate supplies from wadis are adequate in the Abha-Khamis Mushayt area for the next few years, producers ultimately will need to quarry fresh bedrock at one of the many sites available to them. Before opening such a quarry--one that would require a large investment in machinery (including primary crushers, drill rigs, and scales) as well as buildings--the potential sites, including those recommended in this report, should be evaluated by core drilling and appropriate physical tests on the samples.

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