DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

May 16, 1970

Dr. Fadil K. Kabbani
Deputy Minister for Mineral Resources
Directorate General for Mineral Resources
Ministry of Petroleum & Mineral Resources
Jiddah, Saudi Arabia

Dear Dr. Kabbani:

Transmitted herewith are 50 copies:

SAUDI ARABIAN PROJECT REPORT 116

ECONOMIC EVALUATION OF A MARBLE DEPOSIT AND
A KYANITE DEPOSIT NORTHEAST OF AL LITH
SOUTHERN HEJAZ QUADRANGLE KINGDOM OF SAUDI ARABIA

PART I. MARBLE DEPOSIT ON WADI MINSAH
PART II. KYANITE DEPOSIT NEAR WADI AD ARJ

by

David L. Gaskill*

Sincerely,

James J. Norton, Geologist -in-Charge
Saudi Arabian Mineral Exploration
Project

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PART I. MARBLE DEPOSIT ON WADI MINSAH

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MARBLE DEPOSIT ON WADI MINSAH,
SOUTHERN HIJAZ QUADRANGLE,
KINGDOM OF SAUDI ARABIA.

ABSTRACT

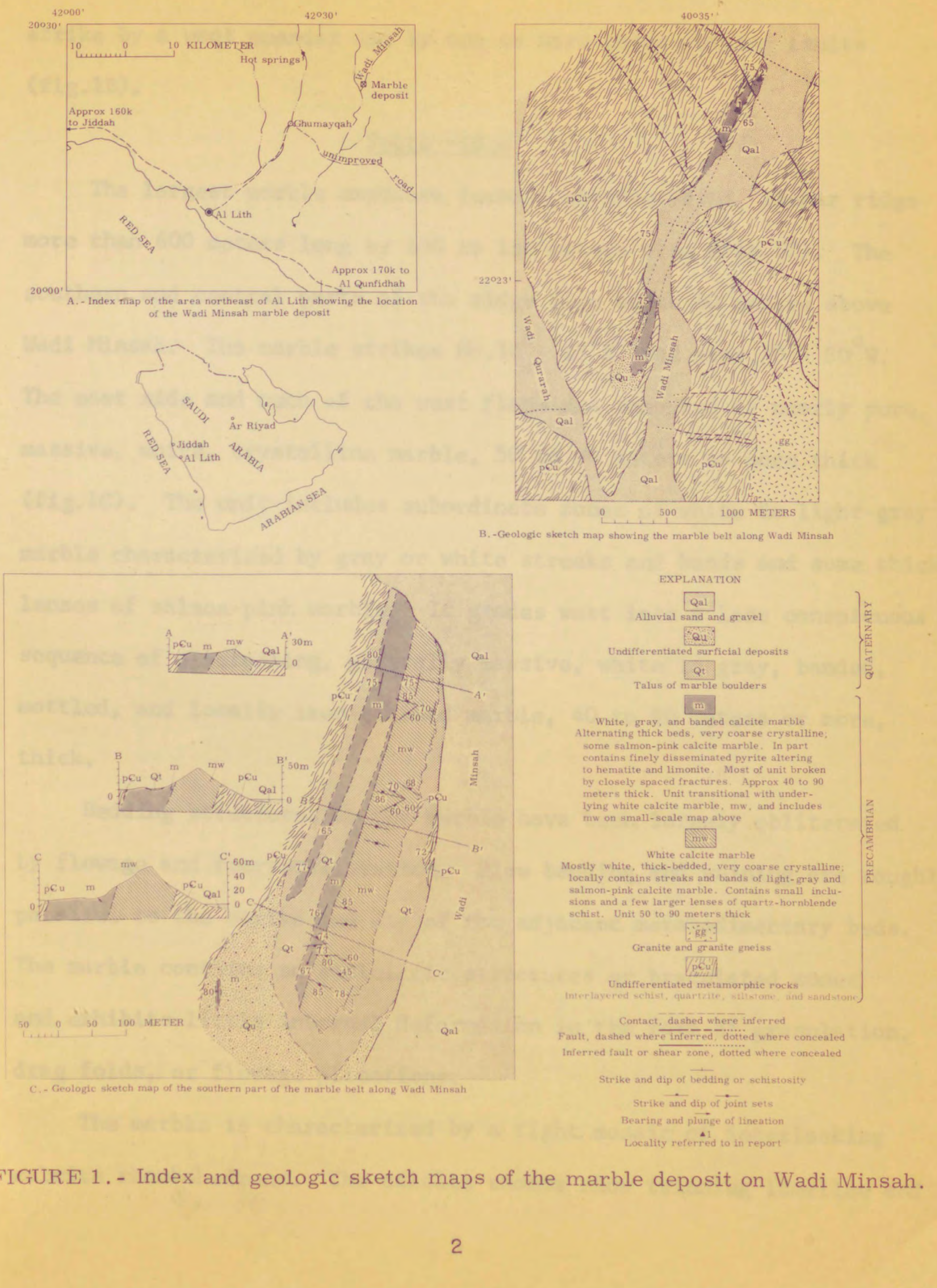
Nearly pure, white and gray banded calcite marble, 40 to 170 meters thick, crops out in three hogback ridges aggregating about 1200 meters in length, located 155 kilometers southeast of Jiddah. The ridges are aligned along a belt over 2.5 kilometers long. The marble is steeply inclined and folded between layers of Precambrian meta-sedimentary rock. The ridges are estimated to contain more than 2 million cubic meters of easily quarried, high-calcium marble. Several hundred thousand cubic meters of uniform, sound marble appears to be suitable for architectural use.

INTRODUCTION

The Wadi Minsah marble deposit is located about 45 kilometers northeast of Al Lith (fig.1A). The deposit extends for about 2.5 kilometers along the west bank of Wadi Minsah above its junction with Wadi Qurarah. It can be reached by an unimproved road from Al Lith, through Ghumaygah, that crosses Wadi Minsah about 15 kilometers south of the marble deposit. The deposit was first reported by Goldsmith (1966, p.80).

GEOLOGY

The Wadi Minsah marble forms three conspicuous ridges of very coarse-crystalline calcite marble. The ridges are separated along



A.- Index map of the area northeast of Al Lith showing the location of the Wadi Minsah marble deposit

B.-Geologic sketch map showing the marble belt along Wadi Minsah

C.- Geologic sketch map of the southern part of the marble belt along Wadi Minsah

FIGURE 1.- Index and geologic sketch maps of the marble deposit on Wadi Minsah.

strike by a wadi meander and by one or more cross-cutting faults (fig. 1B).

South ridge

The largest marble exposure forms a sharp-crested, linear ridge more than 600 meters long by 100 to 150 meters wide (fig. 1C). The southern and central parts of the ridge rise 40 to 50 meters above Wadi Minsah. The marble strikes No. 10°- 15°E. and dips 70°- 80°W. The east side and much of the west flank are composed of nearly pure, massive, white, crystalline marble, 50 to 90 meters or more thick (fig. 1C). The unit includes subordinate zones of white to light-gray marble characterized by gray or white streaks and bands and some thick lenses of salmon-pink marble. It grades west into a less conspicuous sequence of alternating, generally massive, white to gray, banded, mottled, and locally iron-stained marble, 40 to 90 meters or more, thick.

Bedding structures in the marble have been largely obliterated by flowage and recrystallization. Flow banding and veining are roughly parallel to the strike and dip of the adjacent metasedimentary beds. The marble contains no stylolitic structures or brecciated zones and exhibits little internal deformation in the form of granulation, drag folds, or flowage plications.

The marble is characterized by a tight mosaic of interlocking calcite rhombohedrons. The calcite rhombs show twinning lamellae and cleavage striations. In gross aspect the marble exposures appear to be composed of randomly oriented or nearly equidimensional crystals of several sizes. On close examination the grain-fabric mostly shows a faint lineation or elongation of grains with long axes crudely parallel to the strike of the marble. This grain, or schistosity, is somewhat more pronounced toward the margin of the deposit. In places the calcite crystals are stretched into lenzoidal shapes by rock flowage.

Grain size is rather uniform over wide areas of outcrop. Most exposures are composed of crystal rhombs or granules 1 to 4 millimeters across. Average grain diameter probably falls within the 1.5 to 3 millimeter size range. Grain size tends to increase in the thicker and central part of the deposit. Some massive zones of white marble contain crystals up to 11 millimeter across. Grain size variations, however, are subtle and gradational in outcrop.

The marble units are crosscut by close to widely spaced joints and are locally split by expansion fractures. Some massive exposures along the top of the ridge are exfoliating. The attitude of measured joint sets is shown on figure 1C. The more prominent joints are nearly vertical, normal to strike, and are commonly spaced up to 2 meters apart, making large areas of outcrop unsuitable or of limited value for dimension stone. Some sections of the ridge, however, are comparatively free of closely spaced joints. The joints are generally tight and free of mineral coatings. Shear fractures parallel to the bedding are common in marble unit m on figure 1C. Irregular, roughly horizontal to westerly dipping expansion fractures are developed locally, particularly near and along the crest of the ridge. The less pure marbles contain finely disseminated iron. Grains of hydrated iron-oxides are locally concentrated along shears and seams, and weathered exposures of the unit are widely iron-stained.

Outcrops of unit mw on figure 1C exhibit little surface alteration. The white marble tends to weather to a massive, smooth, locally pitted, hard surface. After long physical weathering, the grains separate along crystal boundaries and weather out as individual crystals. The fresh rock breaks clean without fracturing into small pieces.

The marble belt is folded between steeply inclined beds of siltstone, quartzite, and interlayered schist. These beds strike N.10°E. and dip 70°W. along the east side of the ridge. Both the marble and the adjacent layered rocks have been intruded locally by veins of quartz-felsite rock and small irregular dikes, pods, and apophyses of pegmatite. The marble units also include a number of scattered inclusions and lenses of dark-gray quartz hornblende schist particularly in the northern part of the ridge.

The layered rocks in this region are tightly folded, intruded, and domed by igneous bodies. Structural deformation probably accounts for the variation in thickness of the marble along the axis of the ridge. An isolated exposure of gray-banded marble crops out on a small knoll about 100 meters west of the southern end of the ridge (fig. 1C). The knoll may have originated as landslide or block talus derived from the south end of the ridge; however, structural relations indicate it is a bedrock exposure along a swelled section of the marble that may represent a flowage fold.

The marble belt does not crop out south of the junction of Wadi Minsah and Wadi Qararah (fig.1B). The marble either pinches out near the wadi junction or has been offset by faulting.

North ridges

Two smaller exposures of marble form ridges north-northeast of the south ridge along the west bank of Wadi Minsah about 1.3 kilometers upstream (fig.1B). These ridges are aligned along the strike of the marble belt with the south ridge and apparently represent the same lithologic horizon thinning to the northeast.

At locality 1 (fig.1B) marble crops out for a distance of about 350 meters along the crest of a ridge that rises about 40 meters above Wadi Minsah. The marble unit here strikes N.16°E. and dips about 65° W., and is about 60 to 75 meters thick. Beds of silty sandstone and schist underlie the marble to the east, and quartzite overlies marble to the west of location 1. At locality 2 (fig.1B) marble crops out along the west bank of Wadi Minsah and forms a knoll about 12 meters high. Here the marble strikes N.20°E. and dips 75°W. and is in contact with brown-weathering micaceous schist. The two exposures are separated by a topographic depression and offset by faulting.

The marble is mostly white, very coarsely crystalline, and massive, but it includes thick intervals of gray marble with white streaks and bands and white marble with light gray veining. Locally, small dragfold structures are formed along foliation planes. The marble contains thick lenses of schist in the marginal areas.

Some layers of massive, white marble are at least 15 meters thick between partings. The marble is crosscut by vertical joints that trend east-west, and N.55°- 60°E., and dip about 70°S. Joints are generally spaced 1 to 2 meters apart. Expansion seams weaken the rock along the crest of the larger ridge. A few thin micaceous seams are parallel to the grain of the marble locally, particularly near lenses of schist.

Extensive rock inscriptions are engraved on the northernmost exposure of marble at the edge of Wadi Minsah.

CONCLUSIONS

The greater part of the exposed marble is too closely fractured to be suitable for use as dimension stone other than as small blocks, slabs, or ashlar. However, limited areas appear suitable for quarrying large, uniform, cubic pieces and slabs of almost any desirable size.

The fresh marble is very sound and exhibits a relatively high degree of coherence, bonding, and interlocking of calcite granules. The rock is commonly free of glass seams (calcite veins), strain breaks, minute cavities, or minor cracks; the crystalline fabric exhibits almost no intergranulation or brecciation. The rock is resilient and breaks with a smooth conchoidal fracture. Most of the marble is characterized by a uniform composition, texture, and grain size. The marble is practically free of siliceous material. No dolomite or magnesium carbonate zones were recognized. The deposit contains relatively few inclusions. Segregations of allogenic origin are localized and are of limited extent.

Weathered exposures appear to be more resistent to solution than to temperature changes. The rock tends to separate along crystal interfaces after prolonged exposure to physical weathering.

Simple laboratory tests indicate that the marble has suitable finishing qualities. The stone is easily cut, sawed, and polished. The marble would apparently be relatively simple and inexpensive to quarry. High-angle joints normal to the grain (direction of easiest splitting) would facilitate quarrying. Thick sections of marble are essentially free of iron oxides and other impurities, and joints are generally clean and free of mineral matter.

Analyses of samples taken from unit mw on figure 1C on the south ridge contain over 55.12 percent CaO (table 1) or over 97 percent $CaCO_3$.

Table 1. Rapid rock analysis of white calcite marble from Wadi Minsah; S. M. Berthold, Analyst, U.S. Geological Survey, Washington, D.C.

	38004 (Lab no. W-168808)
CaO	55.12*
Al_2O_3	.25
SiO_2	.16
Fe_2O_3	.05
MgO	.01

* $CaCO_3$-98.38- this value calculated from percent CaO found.

Acid insoluble is 1.17 percent, mostly quartz (insoluble in 20 percent HCl).

The bulk of the deposit is composed of white or light-gray, banded marble of desirable hue. The marble has a high degree of translucency that might give it a commercial advantage for use as translucent panels or possibly as memorial or statuary stone.

The average grain diameter of this marble is well above that of most commercial marbles; but the coarse crystalline fabric does not necessarily detract from the durability, inherent strength, or hardness of the rock. Most such coarse-textured marbles are less resisant to abrasion and physical weathering than the finer-grained and siliceous varieties.

The least deformed, thickest, and most desirable grades of marble are exposed in the middle part of the marble belt near or along the main ridge crests. The marble belt thins northeastward mostly at the expense of the least desirable varieties.

Shears and plunging flow structures along the southwest side of the south ridge suggest that the thicker section of marble here may represent a flowage fold. According to Bain (1931 and 1946) marble is concentrated in unusually thick commercial deposits in the axial regions of such folds along the flanks of anticlines and in the bottom of synclines.

Joints and surficial fractures probably decrease in number and variety with increasing depth, and the soundness of the rock should increase with depth. However, the structural position of the marble belt and its lowland location along a major wadi suggest a possible deterioration of the marble by ground water.

The practically pure carbonate rock of this deposit would make a high-calcium lime or a fluxing agent for smelting and refining iron or other metals. The deposit is favorably located in relation to topography, accessibility, and distance from Al Lith. It is, however, rather remote from present large markets.

RESERVES

The marble ridges here are roughly estimated to contain about 2,000,000 cubic meters of easily quarried, high-calcium marble above the level of Wadi Minsah. Reserves at depth are problematical but probably large. The marble belt is apparently continuous along strike under the alluvial cover of Wadi Minsah between the ridges and extends an unknown distance under wadi sediments to the northeast.

The most favorable subsurface target area for drill exploration appears to be the southern part of the south ridge where the marble is thickest and might be expected to thicken at depth due to flowage.

The total volume of high quality dimension stone cannot be fairly estimated on the basis of this examination, but several hundred thousand cubic meters of sound rock, suitable for architectural use, appear to be available above the wadi level.

BIBLIOGRAPHY

Bain, G.W., 1939, Flowage folding: Am. Jour. Sci., 5th Series, vol. 22 pp. 503-530.

Bain, G.W., 1946, Geological, Chemical, and Physical Problem in the Marble Industry: Am. Inst. of Mining and Metall. Tech. Pub. 1261.

Goldsmith, Richard, 1966, Mineral Resources of the Southern Hijaz quadrangle, Kingdom of Saudi Arabia: U.S. Geol. Survey Saudi Arabian Mineral Explor. Project, Tech. Letter 78, 93 p.

PART II. - KYANITE DEPOSIT NEAR WADI AD ARJ

CONTENTS

ILLUSTRATION

KYANITE DEPOSIT NEAR WADI AL ARJ NORTHEAST OF AL LITH, SOUTHERN HIJAZ QUADRANGLE, SAUDI ARABIA

ABSTRACT

Gneissic kyanite quartzite containing 8 to 16 percent kyanite is associated with kyanitic muscovite schist about 200 kilometers southeast of Jiddah. The deposit is estimated to contain approximately 20,000 cubic meters of kyanite. Prospects for finding additional deposits in this region appear to be excellent. The deposit is not believed to be an economically exploitable resource at the present time.

INTRODUCTION

The kyanite deposit is located at approximately 20°26'N.; 40°49'E., about 63 kilometers northeast of Al Lith. The deposit can be reached by an unimproved road beyond Hajarah and thence by trail to Wadi Al Arj (fig.1A).

The deposit was first reported by Goldsmith (1966, p.76). The present investigation was made in March 1967 to evaluate the economic potential of this and other nonmetallic resources in the Al Lith area.

GEOLOGY

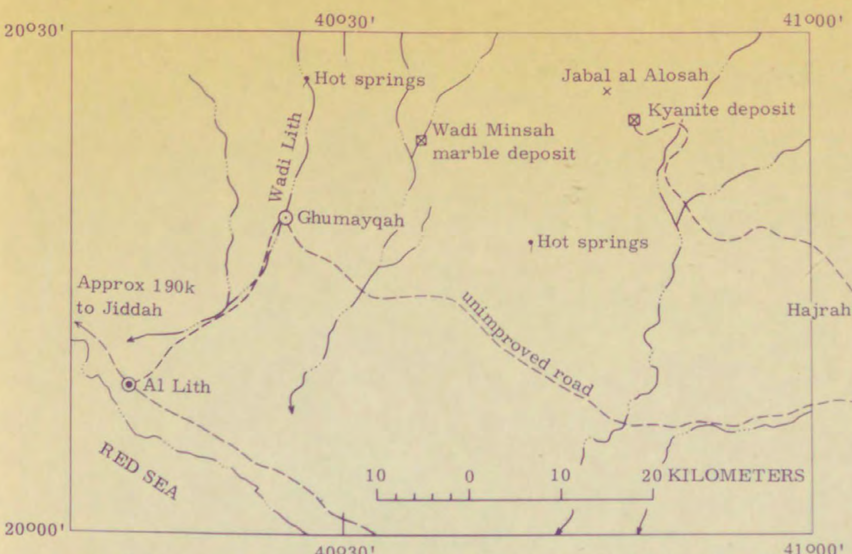
The kyanite is associated with foliated, high-grade metamorphic rocks included in a Precambrian amphibolite schist (Brown and others, 1962). In the Wadi Al Arj area these metamorphosed beds are folded and intruded by granitic rock (Brown and others, 1962). The metamorphic layers here strike north and dip steeply east along the eastern flank of the granitic Jabal Al Alonsah màssif.

Kyanite quartzite

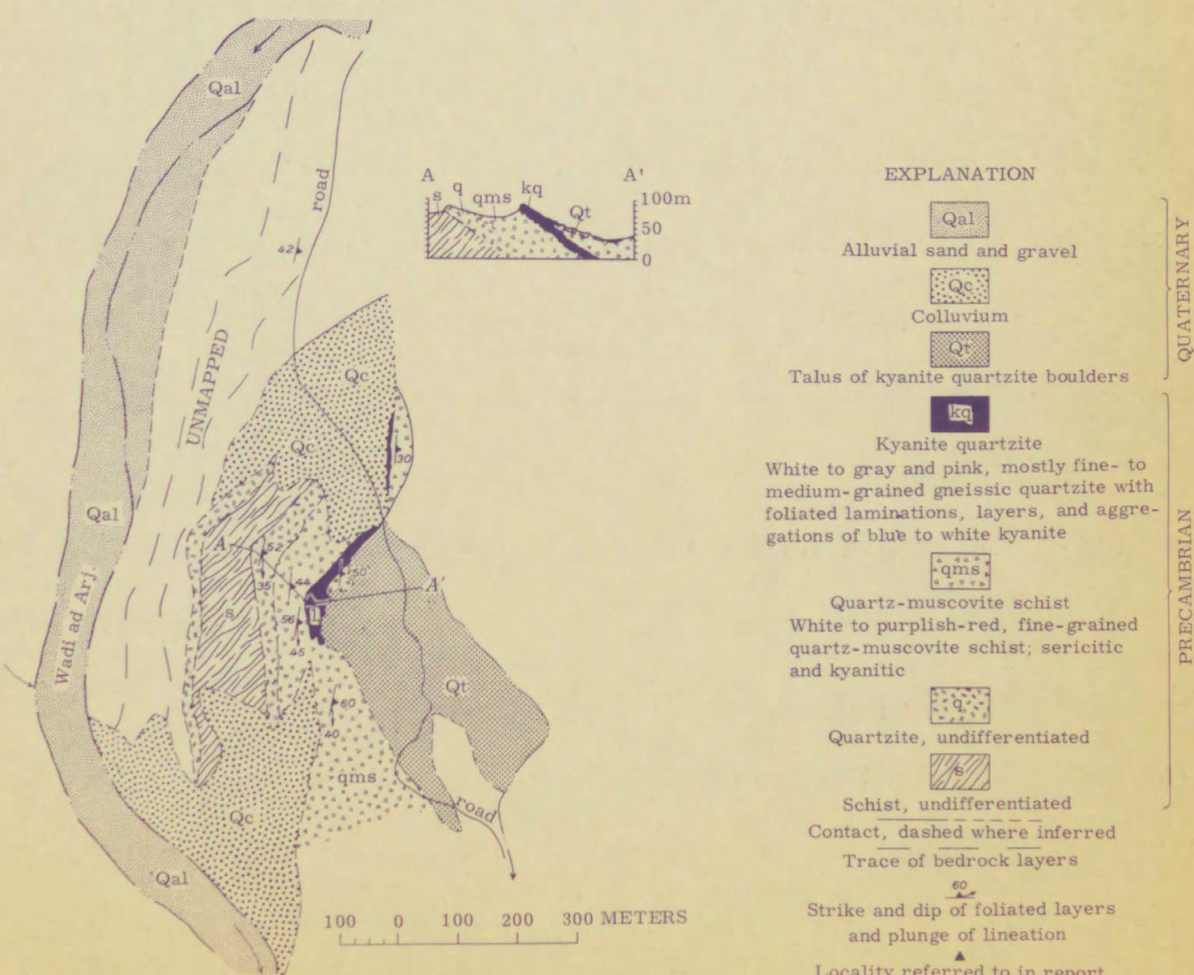
Kyanite-bearing rock is restricted chiefly to a massive, foliated bed or lens of gneissic kyanite quartzite more than 400 meters long and 7 to 20 meters or more thick (fig.1B). The kyanite quartzite is folded between thick layers of kyanitic quartz-muscovite schist. These layered rocks strike roughly north and dip 30 to 60 degrees east, forming ridges and valleys parallel to the regional trend of rock foliation.

Kyanite quartzite caps a prominent knoll. The quartzite appears to terminate at the south end of the knoll, and the enclosing schist may merge into one unit. Structural relationships, however, are obscured here by irregularities of strike and dip along foliation planes and by concealment of contacts under talus.

The wide outcrop pattern at locality 1 on figure 1B is due in part to topographic relief and dip slope exposure, but may also be a consequence of structural thickening due to rock flowage. The thickest layers and segregations of kyanite are found in this vicinity generally exposed in talus blocks. North of the trail, the kyanite quartzite unit is represented by interlayered schist, quartzite, and massive kyanite quartzite 7 meters thick (fig.1B). The base of the section is covered. Kyanite may be restricted to an interval about 3 meters



A.- Index map of the area northeast of Al Lith showing the location of the kyanite deposit near Wadi ad Arj



B.-Geologic sketch map of the kyanite deposit near Wadi ad Arj

FIGURE 1.- Index and geologic sketch maps of the kyanite deposit near Wadi ad Arj.

thick and only the upper half of this interval appears to contain a relatively high percentage of kyanite. Kyanite quartzite is overlain here by 1 meter of quartzitic kyanite schist gradational upward into phyllitic quartz muscovite schist over 16 meters thick.

The kyanite-bearing quartzite of this deposit is typically a hard, dense, light-gray to white, foliated rock composed mainly of very fine- to medium-sized, angular grains of quartz. Kyanite crystals commonly lie along foliation planes that roughly parallel the strike and dip of the quartzite body. Kyanite is found as single blades, bladed masses, and flattened radial aggregations; in pods and knots, as scattered needle-like crystals; and in clusters of thick prismatic crystals. Most commonly the kyanite is in thin tabular crystals that form laminations, thin layers, and lenses separated by layers of quartzite. The crystals are generally oriented with their long axis roughly parallel to fold axes. Thick layers of fine-grained quartzite contain only small inconspicuous crystals of kyanite that have a crude linear orientation. Larger crystals of kyanite are concentrated along crumpled, contorted layers or in small isoclinal folds and are commonly associated with coarse crystalline quartz or lenses of coarse-to very coarse-grained quartz. The kyanite crystals are as much as 13 centimeters long and a centimeter, or more, wide. The bladed forms commonly show cleavage, some exhibit twinning and others are deformed or are disrupted by coarse grains of quartz. Kyanite crystals range in color from white to deep blue. Most have a faint or light greenish-blue cast. The rock weathers brown. Kyanite blades commonly project above the less resistant quartzite groundmass on weathered surfaces. The rock tends to split along kyanite layers and laminations. Grains and small flakes of muscovite and phlogoplite(?) are associated with, and apparently replace, kyanite. Less than one percent of mica appears to be present, but heavy mineral separates suggest that the mica content may be much higher. Accessory minerals include limonite, magnetite, hematite, pyrite(?) rutile, sphene, topaz(?), and specularite.

The kyanite content of the rock is difficult to estimate, and probably varies considerably. Chip samples taken at intervals across the deposit on the northeast slope of the knoll below location 1 range between 8.5 to 15.9 percent kyanite.

Goldsmith (1966) estimated that this rock contains about 5 percent kyanite and figured the volume of kyanite at 75,000 cubic meters. However, I estimate about 20,000 cubic meters of kyanite in a bed averaging 10 percent kyanite, 7 to 20 meters wide by 400 meters long and extending 50 meters down-dip.

Quartz muscovite schist

Layers of sericite schist bounding the kyanite quartzite are well exposed on the west- and south-facing slopes of the knoll at location 1 (fig.1B). The schist is composed of soft, thin layers and laminae of muscovite and sericite interbedded with thin layers of fine, angular quartz grains. The quartz layers are commonly friable, and quartz generally makes up one-half to two-thirds of the rock. The schist contains some kyanite, particularly near and along the contact with the kyanite quartzite. The kyanite appears to be partly altered to mica. Limonite grains are scattered through the rock matrix, and some layers contain small octahedra of magnetite and books of brown mica in a fine sericitic groundmass. The schist ranges in color from white to gray and weathers brown. Pink to purplish and red iron-stained zones are common along the contact with the overlying kyanite quartzite. Fresh exposures have a characteristic silver sheen due to the micaceous layering. Locally, the rock contains large quartz augen.

Kyanite quartzite boulder talus

The east flank of the knoll below location 1 on figure 1B is covered with talus fragments and large blocks of kyanite quartzite. The talus extends several hundred meters downslope. Some of the material may represent landslide debris from the outcrop along the southwest margin of the talus apron. Movement is facilitated along micaceous bedding planes in the underlying schist. This surficial deposit contains a substantial volume of kyanite, perhaps as much as 2000 cubic meters.

EVALUATION AND RECOMMENDATIONS

The kyanite deposit at Wadi Al Arj is very similar to deposits of the Piedmont province of the Southeastern United States where kyanite is concentrated in Precambrian quartzite associated with high alumina schist. Kyanite deposits of this type are thought to form by recrystallization of clay-quartz sand sediments (Espenshade, and Potter, 1960, p.25). Whatever the genesis of these deposits, the metamorphic rock series of the Al Lith-Wadi Al Arj region appear to have excellent prospects for additional discoveries of kyanite-rich rock.

This kyanite deposit is not at present an economically exploitable resource due to its remote location, limited market, small size, and comparatively low kyanite content. Prospecting for kyanite and other high-aluminium silicate minerals in this region is warranted if a local market for refractory materials in metallurgical industries develop or if the world demand improves. World resources of this commodity, however, are large, and other materials compete for the same industrial uses (Klinefelter, and Cooper, 1961, p.1).

Favorable areas for prospecting are indicated by the regional structures and metamorphic rock units delineated on the geologic map of the Southern Hijaz quadrangle (Brown and others, 1962). Favorable areas for prospecting include crests, noses and flanks of anticlines, and roof pendants overlying plutons. Panning of wadi tributaries might prove a useful approach in locating bedrock or placer deposits of kyanite.

BIBLIOGRAPHY

Brown, G.F., Jackson, R.O., Bogue, R.G., and Maclean, W.H., 1962, Geology of the Southern Hijaz quadrangle, Kingdom of Saudi Arabia: U.S. Geol. Survey Misc. Geol. Inv. Map I-210A.

Espenshade, G.H., and Potter, D.B., 1960, Kyanite, Sillimanite, and Andalusite deposits of the Southeastern States: U.S. Geol. Survey Prof. Paper 336.

Goldsmith, Richard, 1966, Mineral Resources of the Southern Hijaz quadrangle, Kingdom of Saudi Arabia: U.S. Geol. Survey Saudi Arabian Project Tech. Letter 78. 93p.

Klinefelter, T.A., and Cooper, J.D., 1961, Kyanite, a material survey: U.S. Bur. Mines, Inf. Circular 8040.