RECONNAISSANCE GEOLOGY OF THE JABAL SHAQRAN QUADRANGLE, SHEET 17/44 B, KINGDOM OF SAUDI ARABIA

by

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ILLUSTRATIONS
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ABSTRACT

The Jabal Shaqran quadrangle lies in the southeastern Asir province, mostly within the westernmost part of the Rub al Khali desert, and is largely covered by Quaternary deposits. Proterozoic crystalline rocks are exposed as inselbergs or rock pediment surfaces along the western border of the quadrangle. The crystalline basement is metavolcanic rock intruded by plutonic to hypabyssal rocks consisting of diorite and gabbro, biotite tonalite gneiss, biotite-hornblende monzogranite, biotite-sodic amphibole granite, and syenogranite to quartz syenite, listed in the inferred order of emplacement. Rhyolite-dacite fels, associated with andesitic to basaltic metavolcanic flow rocks and minor amphibolite, is interpreted to have resulted from metasomatic alteration of the flow rocks during emplacement of granitic plutons.

The Wajid Sandstone, of Cambrian to Ordovician age, is largely a coarse-grained quartz arenite with pebbly phases; common crossbedds indicate north-northwest to north-northeast directions of sand transport. Beds are cemented by iron oxide, carbonate, and minor quartz. The Wajid Sandstone is exposed only in the northwestern and northern parts of the quadrangle.

Quaternary deposits record a climate that became increasingly more arid. They include Holocene and Pleistocene(?) alluvial and fluvial deposits of sand, gravel, and silt, minor carbonate crusts, and eolian sand and silt. Gravel terraces and gravel plains less than 10 m above the present major wadi channels are widespread and commonly are overlain by marly silt along the wadis. Between major wadis, which discharge into the Rub al Khali basin, gravel-topped surfaces are partly covered by a complex of low, sinuous, discontinuous, generally northwest trending transverse sand dunes.

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Normal to this trend, higher and more extensive linear dunes and dune complexes, including seif (irq) dunes as high as 50 m, have encroached southwestward. The transverse and linear dunes may represent two stages of advance separated by a pluvial cycle. Studies of aerial photographs indicate that the dunes have not changed appreciably in shape or size between 1951 and 1959, although some seif dunes have advanced their leading edges 15 to 25 m.

No potentially economic mineral resources other than sand and gravel were found.

INTRODUCTION

The Jabal Shaqran quadrangle (sheet 17/44 B), in the southeastern part of the Arabian Shield between lat 17°30' and 18°00 N. and long 44°00' and 44°30' E. (fig. 1), covers an area of about 2,860 km^2. Most of the quadrangle lies in the westernmost part of the Rub al Khali desert, and bedrock is exposed only as isolated patches of Proterozoic crystalline rocks in the western part of the quadrangle and in a more extensive area of lower Paleozoic Wajid Sandstone in the northwest corner.

Two main drainages, Wadi Najran and Wadi Habawnah, enter the quadrangle from the west and disappear to the east beneath dune sand.

There are no permanent villages or towns in the quadrangle, but the small city of Najran lies about 40 km to the west. The main Najran-Riyadh paved highway in the northwest corner and the Najran-Quamat ash Shawrawrah paved highway crossing the southern part are the only established roads. Vehicle tracks and trails abound in the flatter, less sandy parts of the desert. The Bedouin graze sheep and goats in this part of the Rub al Khali during the winter, and move to the higher and cooler mountains to the west and southwest during the summer months.

A few scattered altimeter observations give altitudes ranging from about 1200 m in the northwest corner of the quadrangle to about 950 m near the eastern boundary. Local relief is mostly less than 100 m from the summits of inselbergs of Precambrian crystalline rocks and hills of Wajid Sandstone to wadi bottoms and adjacent gravel-covered surfaces in the western part of the quadrangle and from the crests of seif dunes to the interdune gravel plain surfaces in the central and eastern parts of the quadrangle.

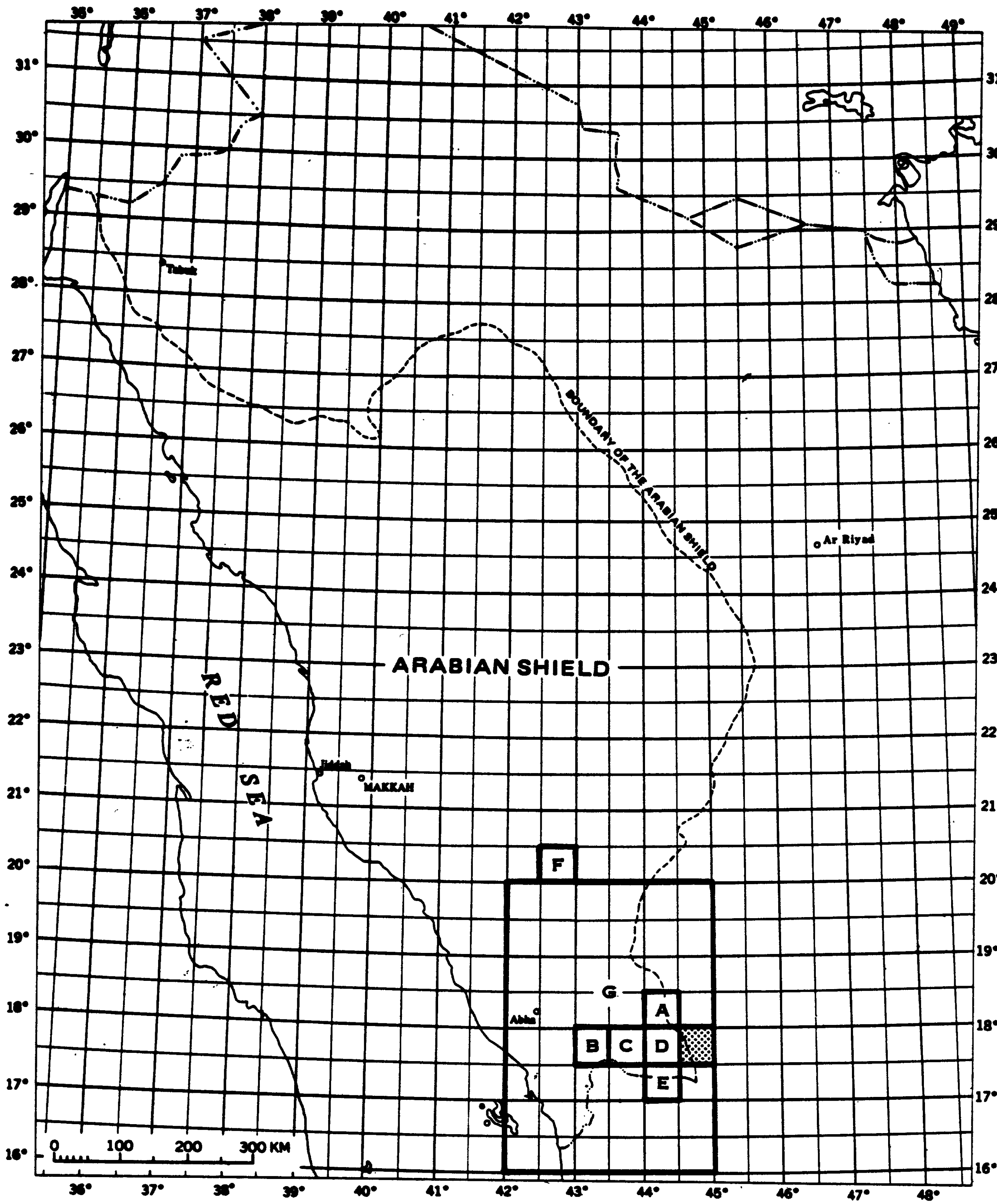

Figure 1.–Index map of western Saudi Arabia showing the location of the Jabal Shaqran quadrangle (shaded) and other quadrangles cited in this report: A, Wadi Wassat (Greenwood, 1980); B, Wadi Atf (Anderson, 1979); C, Mayza (Anderson, 1979); D, Wadi Habawnah (Sable, Unpub. data); E, Najran (Sable, unpub. data. b); F, Al Junaynah (Schmidt, 1980); G, Asir (Brown and Jackson, 1959).

The geology of the region was mapped at a scale of 1:500,000 by Brown and Jackson (1959). The present report is the result of reconnaissance geologic field studies conducted by helicopter mostly during April and May 1979, during mapping of the adjoining Wadi Habawnah (E.G. Sable, unpub. data, 1982) and Najran (E.G. Sable, unpub. data, 1982) quadrangles. Most of the mapping of Quaternary deposits was done by extrapolating from limited field observations and by photogeologic interpretation. Aerial photographs at 1:50,000 scale flown in January 1951 and at 1:60,000 scale flown in January and February 1959 were used to plot field information. The geologic map is compiled on a 1:100,000-scale uncontrolled photomosaic base map made from the aerial photographs. In addition, NASA Land Satellite imagery of the quadrangle was used to study patterns of eolian and alluvial deposits.

The work was done in accordance with a cooperative work agreement between the Ministry of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia and the U.S. Geological Survey.

PRECAMBRIAN ROCKS

Outcrops of Proterozoic felsic and mafic crystalline rocks are limited to a few isolated inselbergs as high as 75 m located near the western border of the Jabal Shaqran quadrangle (pl. 1). The Proterozoic units shown on plate 1 correlate with rock units that are better exposed in the adjacent Wadi Habawnah quadrangle (E.G. Sable, unpub. data, 1982). They consist largely of biotite tonalite gneiss in the southeastern part, biotite-hornblende monzogranite along the central western border, and mixed rhyolite-dacite fels, greenstone, and amphibolite intermittently exposed in areas of low relief farther north. One narrow belt of biotite-sodic amphibole granite is mapped in the northwest. The easternmost outliers in the west-central and southwestern areas are syenogranite to quartz syenite. The plutonic rocks described herein are classified according to the International Union of Geological Sciences system (Streckeisen, 1973, 1976) as shown in figure 2.

Rhyolite-dacite fels

Flinty, conchoidally fractured, gray to reddish-gray fels (rfv) is the predominant rock in a large area along the western border of the quadrangle and is flanked locally by biotite-sodic amphibole granite (gba). The microcrystalline groundmass contains small, sericitized, zoned megacrysts of andesine to albite-oligoclase and a few quartz grains that may be phenoclasts. Potassium

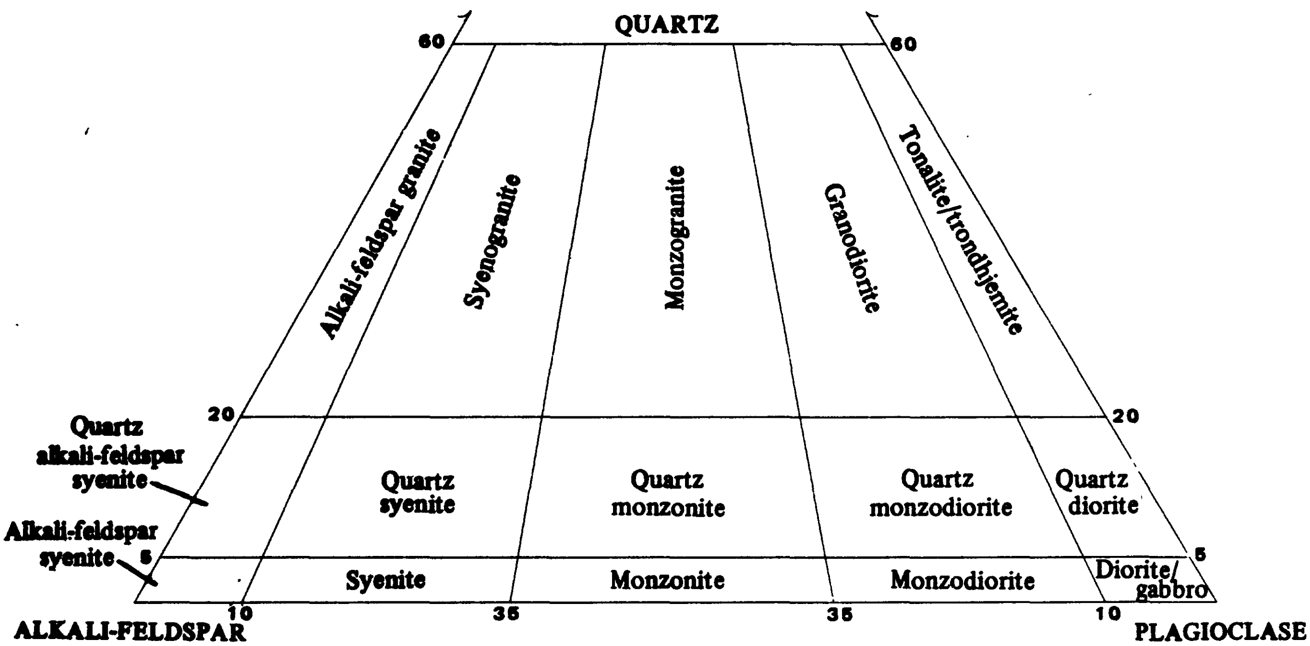

Figure 2.–Plutonic rock classification used for rocks of the Jabal Shaqran quadrangle; classification recommended by the International Union of Geological Sciences (IUGS), Subcommission on the Systematics of Igneous Rocks (Streckeisen, 1973, 1976).

feldspar occurs in the groundmass and replaces plagioclase. Mafic minerals are biotite associated with muscovite and sodic amphibole. In the adjoining Wadi Habawnah quadrangle (E.G. Sable, unpub. data, 1982) riebeckite and arfvedsonite occur in this unit. Greenstone and amphibolite texturally resembling altered diorite are minor constituents.

Petrographic studies of these rocks support the interpretation by Greenwood (1980) that the fels (granofels of Greenwood) is the result of alteration of andesitic to basaltic volcanic flow rocks. The presence of sodic amphiboles suggests that the alteration occurred during intrusion of the adjoining biotite-sodic amphibole granite or during a phase of sodic metasomatism that altered both the granite and fels.

Biotite tonalite gneiss

Gray, fine- to medium-grained, mildly to strongly foliated biotite tonalite gneiss (btg) is characterized by weakly to moderately well defined mineral layering. It consists of subhedral and anhedral andesine, brown biotite, lesser amounts of hornblende and sodic amphiboles, and moderately to highly strained quartz. Color index is 20 to 50. Felsic dikes and granitic impregnations along fabric layering are common. Several small inselbergs of tonalite, distributed over a wide area in the southwestern part of the quadrangle, probably belong to a larger body continuous with that in the Najran and Wadi Habawnah quadrangles (E.G. Sable, unpub. data, 1982). This unit is interpreted to be an orthogneiss, and is probably the oldest intrusive rock in the quadrangle. Zircon from this gneiss in the Najran quadrangle, about 10 km southwest of its exposures in the Jabal Shaqran quadrangle, gave an age of 641 Ma (J. S. Stacey, oral commun., November 1981).

Diorite and gabbro

Medium-grained, gray hornblende-biotite diorite and gabbro (dg) in one small isolated exposure near the west-central boundary of the quadrangle is intruded by granite. The diorite and gabbro resemble the early metadiorite-metagabbro unit of the Wadi Habawnah quadrangle (E.G. Sable, unpub. data, 1982) in that they contain large cumulate clusters of biotite. The rocks, which were not examined microscopically, may be a mafic variant of the biotite tonalite gneiss unit.

Biotite-hornblende monzogranite

Biotite-hornblende monzogranite (mgb) is exposed along the central western quadrangle boundary and extends about 1 km into the adjoining Wadi Habawnah quadrangle; it resembles the common calc-alkalic granite widely exposed there. In the Jabal Shaqran quadrangle, the outcrop pattern suggests that exposures may be part of a large circular or ring structure concealed beneath eluvial sediments to the east. The monzogranite is pink to orange, fine to medium grained, weakly gneissose, and contains white sodic oligoclase and pink microcline, slightly perthitic in part. Color index is less than 10. Accessory minerals include abundant apatite along with zircon and magnetite. Epidote is common.

Biotite-sodic amphibole granite

Biotite-sodic amphibole granite (gba) exposed along the northern part of the western quadrangle boundary is part of a circular body, the Jabal Ya'arah pluton, most of which is in the adjoining Wadi Habawnah quadrangle. It is pink, fine to medium grained, locally porphyritic, weakly gneissose, and ranges compositionally from monzogranite to syenogranite. Mineralogy is similar to that of the biotite-hornblende monzogranite but includes arfvedsonite and riebeckite as discrete grains and as rims and patches associated with hornblende. Megacrysts of pink, nonperthitic, glassy microcline less than 2 cm long resemble the porphyroblasts in the Wadi Aashiba gneiss complex to the southwest in the Wadi Habawnah quadrangle.

Syenogranite and quartz syenite

Leucocratic, pink, fine- to medium-grained, structureless to moderately foliated syenogranite and quartz syenite (sg) occur as two small inselbergs at the north edge of Wadi Najran in the southwestern part of the quadrangle. The rocks are allotriomorphic, equigranular, and contain perthitic microcline, quartz, albite-oligoclase, less than 5 percent arfvedsonite, aegirine-augite, and biotite, associated sphene, and accessory magnetite, allanite, and pyrite.

About 17 km farther north, the easternmost exposure of crystalline rocks is a small hill of pale-red to grayish-red, leucocratic, fine- to medium-grained porphyritic syenogranite. Bimodal-sized grains of quartz, perthitic microcline, and antiperthitic albite are major constituents. Vaguely zoned sericitized plagioclase believed to be albite-oligoclase also occurs in part as phenocrysts. The rock contains less than 3 percent brownish-gray biotite. Accessory minerals include sphene, muscovite, and pyrite; epidote is a common subordinate mineral.

Quartz syenite and syenogranite in the two areas are similar in mineral composition and texture except that sodic amphiboles are not present in all exposures. The syenogranite is similar in composition to syenogranite in the adjoining quadrangles to the west and southwest, but appears to be separated from it by less alkalic rocks. These easternmost exposures of granitic rocks may be near the westernmost edge of one or more large plutons now hidden by Quaternary deposits of the Rub al Khali.

PALEOZOIC ROCKS

Wajid Sandstone

The Wajid Sandstone (OЄw) of Ordovician and Cambrian age (Brown and Jackson, 1959; Brown, 1970; Hadley and Schmidt, 1975) overlies Precambrian rocks with pronounced angular unconformity. The underlying erosion surface has been reported by many authors to be remarkably planar over broad areas, and a contour map of the Wajid base in the adjoining Wadi Wassat quadrangle to the northwest (Greenwood, 1980) shows that the erosion surface strikes north and dips gently and generally uniformly eastward.

The Wajid Sandstone crops out in an area of about 160 km^2 in the northwest corner of the Jabal Shaqran quadrangle and extends much farther north (Brown and Jackson, 1959). Much of the outcrop area is covered by sand and colluvium, through which hills of Wajid Sandstone project to heights of 20 to 50 m. The Wajid extends at least 15 km east beyond the principal area of outcrop as indicated by a few outliers and pediment surfaces containing abundant residual sandstone debris. The Wajid Sandstone is predominantly a mineralogically mature, moderately well sorted quartz arenite. Ranging from gray to reddish gray, it is composed of round to subround grains of strained to unstrained quartz, quartzite, chert, and scarce microcline. Quartz overgrowths on older quartz grains are common. Most of the sandstone is poorly cemented by iron oxides and carbonate, but near the base it is well cemented by iron oxides and hydroxides. Iron hydroxides also form botryoidal, stalactitic, and irregularly shaped concretions and massive layers in the basal part of the Wajid. Conglomeratic layers of subround, ovoid, and irregularly shaped pebbles of white, gray, pink, and green quartz and brown chert occur locally near the base and as lenses higher in the unit, particularly near the base of crossbeds. Planar and trough sets of crossbeds commonly consist of very coarse grained sandstone with clay galls. Crossbeds range from 1 to 3 m in thickness, and individual foreset beds are less than 12 cm thick. Planar crossbedding dips mostly between 24° and 28° north-northwest to north-northeast, and reflects northward directions of transport over a broad area. No "red-bed" siltstone facies, such as that described farther west (Anderson, 1979; E.G. Sable, unpub. data, 1982) was seen in this quadrangle, although the basal sandstones contain abundant iron oxides and may be the stratigraphic equivalent of the red-bed section. Linear ridges of resistant Wajid Sandstone in the northwest corner of the quadrangle trend north-northwest. Indurated sandstone in the ridges is cemented by carbonate and quartz(?), probably localized along fractures or faults.

The base of the Wajid where exposed about 1 km north of Wadi Habawnah slopes gently east-northeastward. The slope is structural, probably related in part at least to subsidence of the Rub al Khali basin (Anderson, 1979, p. 27). Scattered altimeter readings along the base, for a distance of about 65 km from the western boundary of the Wadi Habawnah and Najran quadrangles to the northwestern corner of Jabal Shaqran quadrangle, indicate that the average slope is about 10 to 10.5 m/km. This slope is slightly less than that calculated by Greenwood (1980) for the western part of the Wadi Wassat quadrangle (11.5 m/km), and considerably less than that calculated for the eastern part (17 m/km). The increased slope toward the Rub al Khali in the eastern part of the Wadi Wassat quadrangle indicates a down-warping of the base in that area. Altimeter readings in the northwestern part of Jabal Shaqran quadrangle and the northeastern part of the Wadi Habawnah quadrangle provisionally suggest that the slope of the Wajid base also steepens there. A north-trending hinge line may thus exist just west of the Jabal Shaqran quadrangle, with the east side downwarped toward the Rub al Khali basin.

QUATERNARY DEPOSITS

Quaternary deposits include alluvial, eolian, colluvial, and possible thin lacustrine sediments. The units were mapped on the basis of a few ground observations augmented by study of 1:60,000-scale and 1:50,000-scale aerial photographs. Terminology relating to sand dune deposits and forms generally follows that of McKee (1979). Information given here is largely qualitative.

The geologic map provides a framework for future quantitative studies.

Eolian deposits

Eolian sediments consist mostly of sand in dunes that overlie interdunal, gravel-plain deflation surfaces. Mapped areas of differentiated dune forms include linear southwest-trending dunes (Qdl_1, Qdl_2) and areas of dunes transverse to the linear dunes (Qdt). Eluvial deposits that are not mapped include sand that fills depressions in upland areas such as the areas underlain by Wajid Sandstone, small climbing dunes along the northeastern flanks of hills, and thin sheets of sand and silt in many flat areas.

The transverse dune unit (Qdt) is so named because most dune crests in broad areas are normal to trends of the linear dunes. Transverse sand dunes are commonly less than 2 to 3 m high, sinuous or crescentic, complex, and trend west-northwest. They are not classic parabolic dunes, but resemble ripple marks produced by an aqueous flow across a planar surface. Many appear to be partly stabilized by vegetation and thus older than the linear dunes; some may be contemporaneous with the linear dunes. The sand composing these dunes is fine to medium grained and pale to light brown, in contrast to the generally reddish sand in the linear dunes. Dune slip faces are toward the southwest. At the time fieldwork for this report was done, little or no difference in shape or location could be detected between any of the present transverse or remnant dunes and those same dunes seen on aerial photographs taken in 1951 and 1959.

Included in the transverse dune unit are well- to poorly defined, south-southwest- to southwest-trending lobate sand dunes north of Wadi Najran shown by formlines on the geologic map (pl. 1). These dunes support sparse vegetation and may be in part stabilized; many seem to be dissipating by wind action. They are interpreted to be remnants of linear dune termini, and may represent the remains of a former, more extensive field of linear dunes that are now partially stabilized. If so, the active linear dunes encroaching on them represent a younger, separate dune regime resulting from the present arid climate. An interval between the old and new linear dune regimes may have been pluvial, perhaps the Holocene pluvial of Arabia 6,000 to 9,000 years ago (McClure, 1976).

Linear dunes, composed mostly of fine- to very fine grained, light-brown to reddish-orange, well-sorted sand, have encroached over transverse dunes and gravel plains. They are the youngest dune sands in the area, active, and of two general types: 1) relatively short, very straight, rather regularly spaced, narrow dunes 1 to 3 m high, which, with associated sheet sand, thinly cover gravel-terrace or gravel-plain deposits (Qdl_2); and 2) complex, dominantly linear seif or irq dunes about 15 to 50 m high (Qdl_1). These dunes are connected to feather dunes, to dune fields that contain smaller linear, transverse dunes, and to crescentic dunes, most of which are on the leeward (northwest) side of seif dunes and tangential to them. Sand aprons and sheet sand also are included in these complexes. Slip faces of most seif-dune crests face northwest.

Blowing sand and the lack of vegetation in the upper part of dunes indicate that the linear dune deposits are currently active, but comparison of 1951 and 1959 aerial photos and NASA 1973 Landsat imagery showed little change in dune shape or position where some recognizable feature such as vegetation could be used as a datum for comparison. A few measurements show that the maximum advance of seif dune termini during this period was 15 to 25 m.

Alluvial and colluvial deposits

Pediment deposits (Qpd) occur in broad areas in the northern part of the quadrangle and consist of locally derived, mostly angular sand- to cobble-sized clasts of Wajid Sandstone. Undissected pediment deposits and bedrock surfaces on partly exposed granite and fels along the western margin of the quadrangle are mapped as bedrock; their slopes seem to be at an equal grade with present stream systems. Undissected pediment surfaces are characterized by black patina and desert varnish.

In some areas along major drainages, vague outlines of a higher terrace or terraces are present perhaps 1 to 3 m above younger gravel terraces (Qtg). The surfaces of these older terraces form a wide gravel and sand plain (Qgp) probably of alluvial origin. Lag gravel consisting of pebbles and cobbles of crystalline rocks and Wajid Sandstone is interspersed with thin eolian sand and silt. In places, the gravel is poorly cemented by carbonate. Some of this unit as mapped probably includes lateral equivalents of gravel terrace deposits (Qtg), but parts seem to represent one or more higher, older surfaces.

Elongate interdunal areas parallel to the linear dunes and dune complexes lie en echelon along generally east-northeast trends. Flat and relatively sand-free, they are covered mostly by silt poorly cemented by carbonate but covered in part by granule- to cobble-sized clasts and local concentrations of pebble to cobble gravel. Most of the clasts are quartz and crystalline rocks. These deposits probably correlate with the gravel-plain deposits (Qgp) and are included with them on the geologic map. Very crude to well-flaked man-made artifacts are found in some of the interdunal areas. At two localities, a few centimeters of carbonate-cemented duricrust was found about 7 cm below the deflation surface and is underlain by light-brown silt. A few small interdune areas, seen on aerial photographs but not mapped separately, contain white deposits, probably carbonate or silt, or perhaps marl resulting from evaporation of transient ponds formed during heavy rains, such as the Holocene playa lakes described by McClure (1978, p. 261-262).

Terrace deposits of sand and gravel (Qtg) along major wadis contain cobbles and small boulders. Their tops are less than 2 m above present flood plains. Locally they contain abandoned, sinuous meander scars. Contacts with younger alluvium are indistinct in eastern parts of the quadrangle.

Buff-colored, locally calcareous loessic silt to silty marl (Qst) with minor interbedded sand and gravel lenses occurs along major wadis as terraces that erode to vertical, loess-like cliff faces. Deposits of this unit overlie the gravel terrace unit (Qtg), and may be of mixed eolian-alluvial origin, perhaps derived in part from previously existing upland loess. The unit is not well exposed, but is estimated to be at least 4 m thick. Similar deposits are described to the northwest in the Wadi Wassat quadrangle (Greenwood, 1980). Greenwood (1980, p. 22) and Schmidt (1981, p. 47) interpret the silts to have been deposited during pluvial cycles, perhaps 6,000 to 9,000 years ago, prior to the arid conditions that now exist.

Alluvial fans and pediment deposits (Qfp) are composed of unconsolidated, poorly sorted, generally subangular sand- to small boulder-sized gravel through which, in places, low planar surfaces of bedrock project. The Qpf unit also includes alluvium in tributary streams of the larger wadis as well as some eolian sand either filling depressions or as small climbing dunes.

Colluvium derived from the Wajid Sandstone (Qcw) is mapped along tributary wadis and low slopes in the northeastern part of the quadrangle. Materials are unsorted, sand- to boulder-sized angular fragments of sandstone and iron oxides, which occur in distinctive terrace-like features that contour the slopes. These features are probably the result of mass wasting and sheet flooding.

Wadi alluvium (Qa) is mapped in channels and on flood plains of Wadi Habawnah and Wadi Najran. Present flood plains are as much as 4 and 3 km wide, respectively. Although low floodplain terraces 1 m to several meters high indicate that the wadi is entrenching, the braided channel patterns in wide flood plains suggest dominant aggradation because of decrease in gradient as the wadis enter the Rub al Khali basin from the mountain valleys to the west. Downstream, the wadis are aggradational because they become choked and dammed by eolian sand. The youngest sediments are moderately well sorted sand and silt with scattered pebble- to cobble-sized clasts. In the wide flood plain of Wadi Habawnah south of Jabal Shaqran, crusts of calcareous silt and clay in the alluvial deposits have resulted from evaporation of ephemeral ponds after flooding of the wadi.

Correlations

Correlation of Quaternary units with those of McClure (1978) is in part speculative. The gravel-plain deposits (Qgp) in interdunal areas may be Pliocene alluvium reworked during the Pleistocene period (McClure, 1978, p. 258, fig. 85). McClure's paleosol surfaces are probably represented in the interdunal areas. The transverse dunes may in part be thin discontinuous remnant equivalents of McClure's late Pleistocene paleodune unit. The linear seif dunes and dune complexes correlate with McClure's recent cresting eolian (seif) dunes of Holocene age.

Najran weather records

Records of the present wind regime in the Najran area taken at the Najran airport are sparse and cover only a few years. Figure 3 shows relative frequency of wind directions in 1977 from data obtained by the Ministry of Defence and Aviation (1977). Winds from the east to northeast are predominant. During 1977, annual mean wind velocities were about 3 to 6 knots. Maximum wind velocities of 35 to 30 knots were from the northeast and east, respectively; they ranged from 22 to 35 knots from January through May, and 22 to 30 knots from June through October. Occasional west to northwest winds of short duration ranged from 17 to 21 knots.

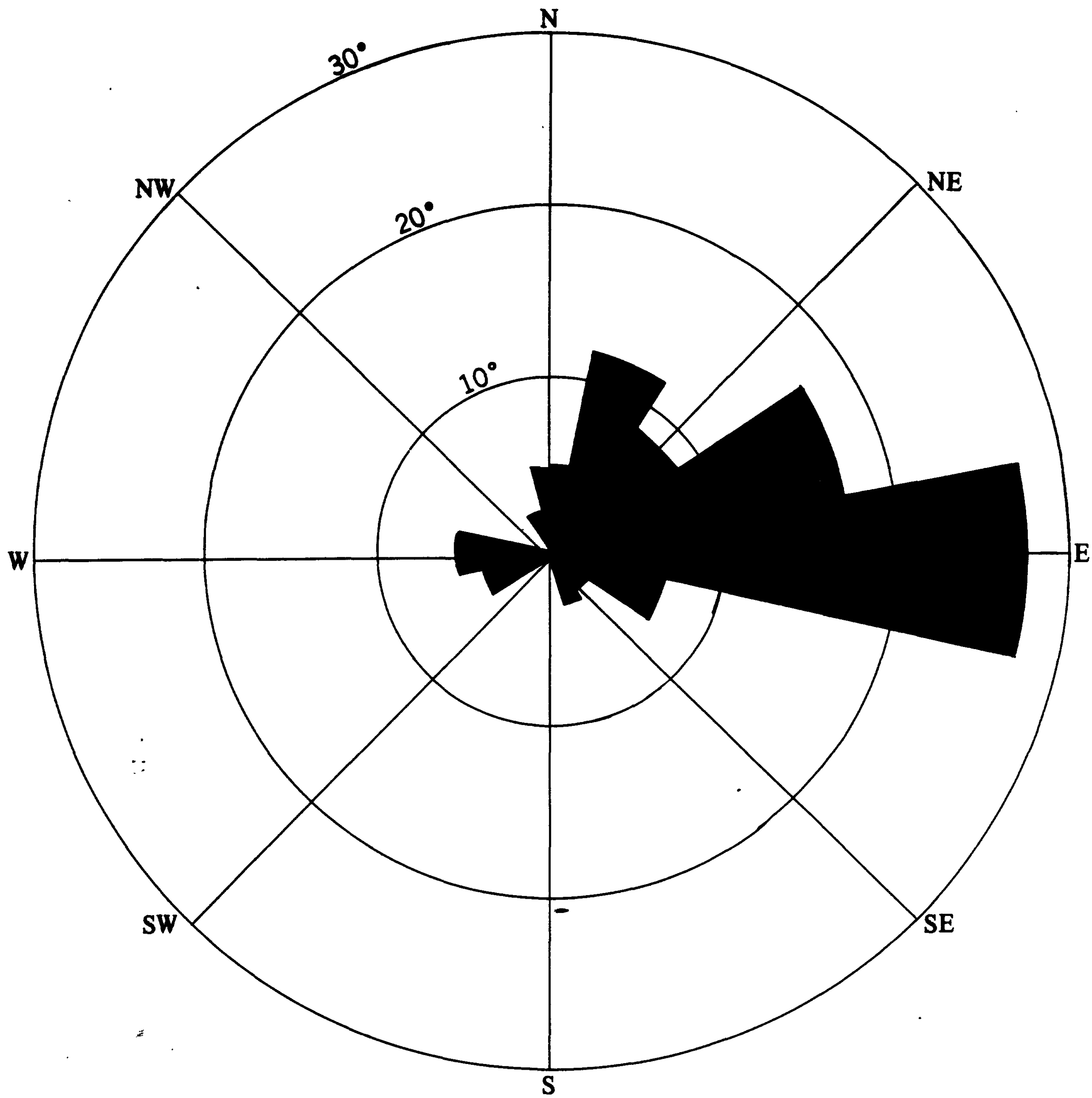

Figure 3.–Rose diagram showing relative frequencies of wind directions at Najran, Kingdom of Saudi Arabia, in 1977 (in percent). (Annual Environmental Report of the Ministry of Defence and Aviation, 1977.)

The east and northeast directional and velocity vectors of the winds are probably responsible for the creation of the longitudinal and transverse dunes. The shapes and orientations of the transverse dunes are more affected by local topography; if the 1977 records were representative and could be applied on a regional basis, it would appear, with a predominance of east winds, that the longitudinal dunes would strike more westerly than southwesterly.

Precipitation at Najran in 1977 totalled 67.9 mm, the largest 24-hour precipitation being 23.8 mm. If representative, this value plus the obviously high evaporation rate in the area indicates conditions too arid for the stabilization of dune sand by vegetation.

ECONOMIC GEOLOGY

No evidence of potentially economic mineralization was observed in rocks or sediments of the Najran quadrangle. Iron oxide and hydroxide are locally abundant in the lower part of the Wajid Sandstone. Sand and gravel are abundant along major wadis, and well-sorted sand is present in dunes.

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