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GEOLOGICAL RECONNAISSANCE OF THE WADI AL LITH-WADI SALIBAH AND JABAL AFAF AREAS

BY

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ABSTRACT

The area is underlain by northeast-trending belts of Late-Proterozoic volcanic, volcaniclastic and sedimentary layered rocks separated by a variety of younger plutonic intrusions. The former strata comprise andesitic lavas, mafic, intermediate and siliceous volcaniclastic schists, and a wide range of sedimentary schists. Geological mapping has enabled the stratigraphy and structure of the area to be reinterpreted.

As published reconnaissance geological maps contain no lithological details of the layered rocks, environments inferred to have potential for volcanic-related base- and precious-metal mineralization, especially the siliceous metavolcanic rocks, were first identified by photogeological interpretation. They were then investigated by detailed geological mapping along selected traverses, extensive rock-chip sampling, geophysical prospecting, and wadi-sediment geochemistry.

The numerous mineralized outcrops found include barren, cupriferous and, in a few cases, zinc-bearing stratiform ironstones in siliceous volcaniclastic and sedimentary schists, stratiform copper- and gold-bearing rhyolitic cherts, and fracture-related copper mineralization within andesitic metavolcanic rocks. Auriferous quartz veins are rare.

All the occurrences are too small to warrant further investigation, and the area appears unlikely to contain any significant base- or precious-metal mineralization.

CONTENTS

FIGURES

TABLE

PLATES
(in pocket at back)

INTRODUCTION

1.1 SCOPE AND OBJECTIVES

During the 1399-1400 field season, Riofinex carried out a rapid regional reconnaissance for base- and precious-metal mineralization over the Jabal Sita - Wadi al Lith area (Bowden and Morfett, 1979). Host rock environments favourable to volcanogenic base- and precious-metal mineralization were identified in the Wadi al Lith - Wadi Salibah area and a further program of regional mapping and sampling was recommended.

The present report describes the results of further detailed reconnaissance in Wadi al Lith - Wadi Salibah area during the 1401-02 field season, as well as subsequent detailed investigations of specific exploration targets carried out during 1402-03. The latter work also included the investigation of targets in the Jabal 'Afaf area, some 50 km to the south. This work was conducted under sub-projects 3.01.16 (Regional Assessment - Wadi al Lith - Wadi Salibah), 3.01.42 (Regional assessment - Jabal 'Afaf) and 3.11.63 (Shield layered formations - Prospecting, Wadi al Lith - Wadi Salibah) of the Deputy Ministry for Mineral Resources.

The objectives of the investigation were to undertake systematic geological reconnaissance aimed primarily at the rapid identification of volcanogenic stratiform base- and precious-metal mineralization. The possibility of other types of mineralization being present in the area was not overlooked.

1.2 LOCATION AND ACCESS

The Wadi al Lith - Wadi Salibah area lies along the Red Sea coastal plane, some 200 km south of Jiddah (Figure 1). The area centres on 20°30'N and 40°30'E, is approximately 100 km long and 40 km wide, and is elongated in a northeasterly direction. The Jabal 'Afaf area measures some 15 x 10 km and lies a further 20 km to the southeast (Figure 2).

FIGURE 1

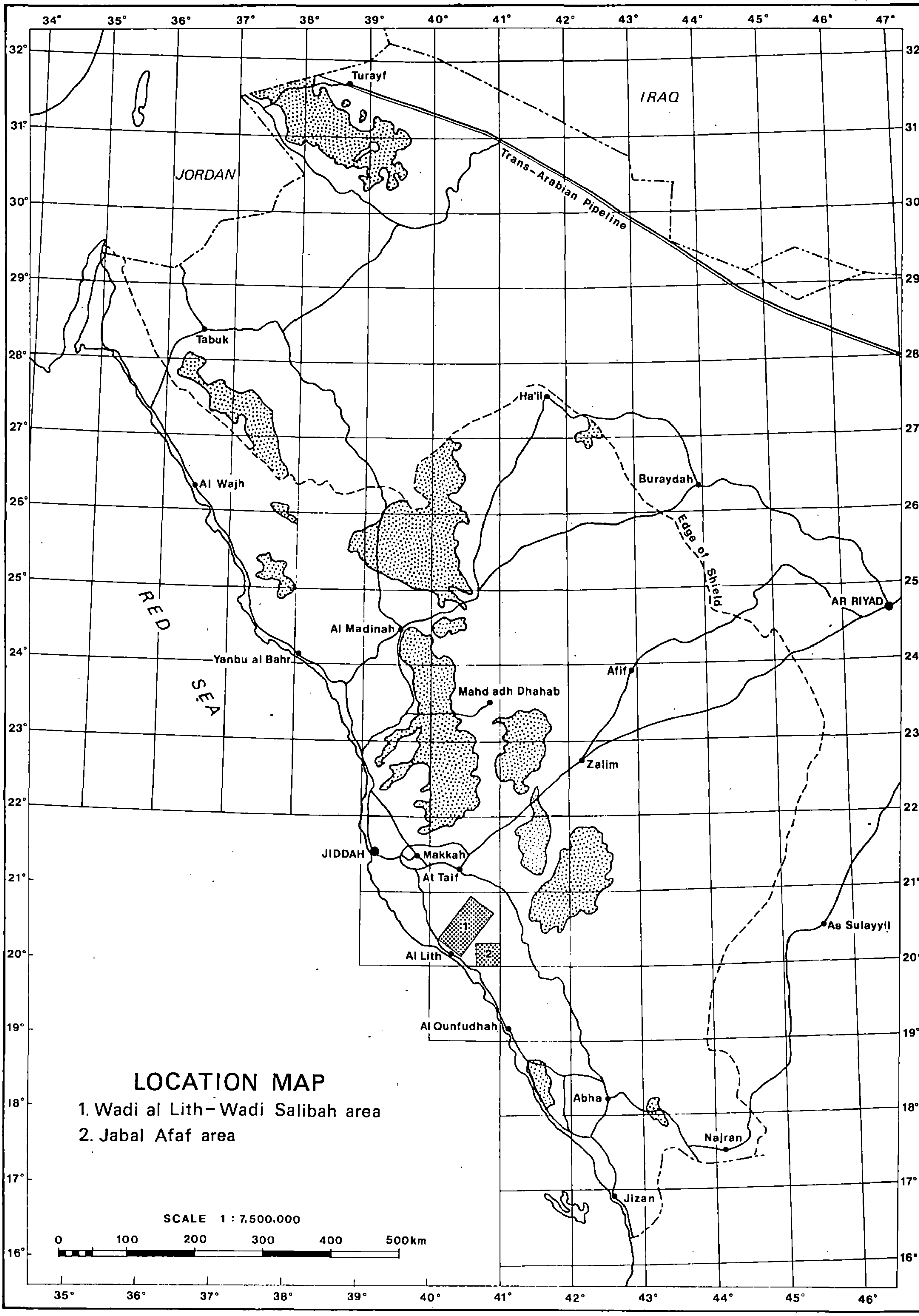
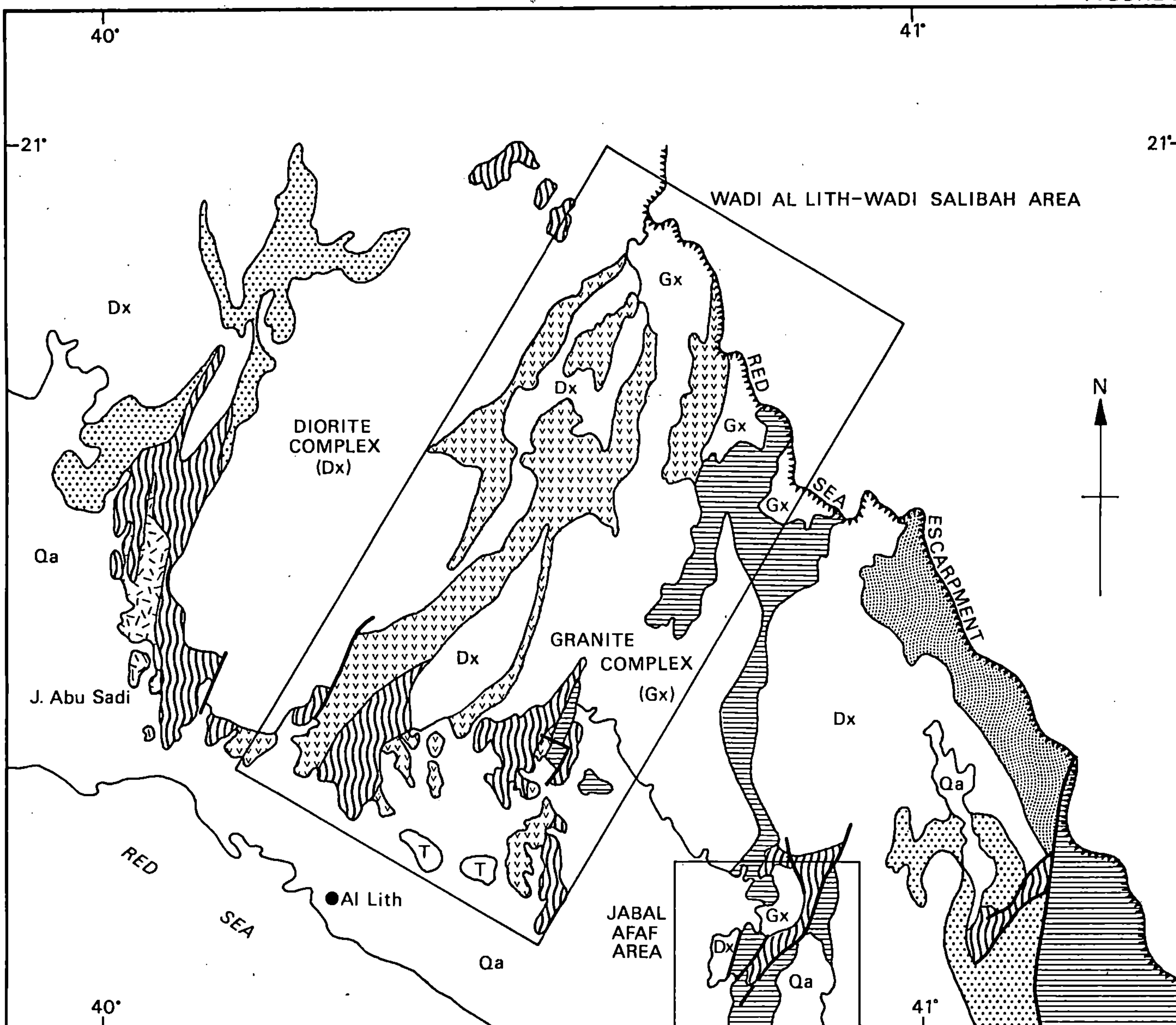

Turayf
IRAQ
JORDAN
Trans-Arabian Pipeline
Tabuk
Ha'il
Buraydah
Edge of Shield
Al Wajh
RED SEA
Al Madinah
AR RIYAD
Yanbu al Bahr
Afif
Mahd adh Dhahab
Zalim
JIDDAH
Makkah
At Taif
Al Lith
As Sulayyil
Al Qunfudhah
Abha
Najran
Jizan
LOCATION MAP
1. Wadi al Lith–Wadi Salibah area
2. Jabal Afaf area
SCALE 1 : 7,500,000
0
100
200
300
400
500km

FIGURE 2



WADI AL LITH–WADI SALIBAH AND JABAL AFAF AREAS
REGIONAL GEOLOGICAL SETTING

(Modified after Bowden and Morfett, RF-OF-01-10)

10 0 10 20 30 40 50kms

Scale 1:1 000 000

LEGEND

Qa	Quarternary alluvium
	Amphibolite, biotite–hornblende schist
	Metasedimentary schists
	Paragneiss, migmatite
T	Tertiary sedimentary rocks
	Felsic volcaniclastic rocks
	Predominantly intermediate volcaniclastic rocks
	Mafic metavolcanic rocks

The area consists of rugged mountainous terrain which become precipitous in the northeast where it extends up to the Red Sea Escarpment. The area is dissected by several major wadis which flow southwestward to the Red Sea. Elevations vary from near-sea level to as much as 2,000 m. The Jabal 'Afaf area is much less rugged and consists of low hills adjoining the flat coastal plain. Orographic rain brings seasonal precipitation to the area adjoining the Escarpment and some of the major wadis are known to flow throughout the year. Natural vegetation is minimal.

The village of Al Lith (Figure 2) is the major commercial centre in the area and is connected by tarred road to Jiddah. Ghumaygah, a small trading centre, is located along Wadi al Lith. Access is difficult. Tracks along the major wadis can be travelled by four-wheel-drive vehicle, but all other areas have to be reached on foot or by helicopter.

1.3 PREVIOUS INVESTIGATIONS

1.3.1 OTHER ORGANIZATIONS

The earliest published geological information on the area is incorporated on the 1:500,000-scale geologic map of the Southern Hijaz quadrangle by Brown and others (1962). The entire investigation area has been mapped at 1:100,000 scale by geologists of the USGS and is covered by the following maps:

Quadrangle 20/40A - Wadi Sadiyah (Wier and Hadley, 1975)
20/40B - Wädi Salibah (Cater, 1977)
20/40C - Al Lith (Hadley and Fleck, 1980)
20/40D - Jabal 'Afaf (Hadley and Fleck, 1980)

Mineral investigations have centred on the northern part of the area where scheelite mineralization was first identified by the DGMR in 1964 (Goldsmith, 1971), and further investigated by Kouther (1966) and the USGS (du Bray and Doebrich, 1981).

1.3.2 PREVIOUS RIOFINEX PROGRAMS

The Wadi al Lith - Wadi Salibah area was the focus of one of six "Other Review and Assessment Projects" selected for investigation during the 1399-1400 field season under the 'Review of Mineral Potential' program (Project 5.16, Second Sectoral plan). Vehicle-borne reconnaissance and prospecting was carried out as well as broader regional reconnaissance with helicopter support (Bowden and Morfett, 1981).

This reconnaissance outlined several areas of siliceous volcanic rocks which were inferred to constitute an attractive environment for the development of volcanogenic massive sulphide mineralization. Furthermore, in several areas a well developed pyritic stratigraphy and occasionally massive ironstones were found to be present within the siliceous volcanic rocks. One such ironstone (Location 221, Ghumayqah Northwest, MODS 2088) was found to carry anomalous assay values of 1,900 ppm Cu, 450 ppm Pb, 170 ppm Zn and 7.6 ppm Ag.

Despite the fact that little mineralization of note had previously been recorded from this area, the results of the reconnaissance investigation were considered sufficiently encouraging to justify further regional follow-up exploration.

2 GEOLOGY

2.1 INTRODUCTION

The following description of the geology of the Wadi al Lith - Wadi Salibah and Jabal 'Afaf areas is based on personal observations and represents a summary of two internal Riofinex Reports (Bavin, 1983a; Grootenboer, 1985) which are stored in Data File RF-DF-01-04.

Geological mapping was confined to the recording of geological observations along selected foot traverses across representative geological environments. The mapping was aimed at identifying the geological characteristics of these environments, assessing their mineral potential and gaining an understanding of the geological setting of any mineralization present. Little attention was paid to problems of regional stratigraphy and/or structure.

2.2 REGIONAL SETTING

The Wadi al Lith - Wadi Salibah area is underlain by Late Proterozoic volcanic, volcaniclastic and sedimentary "layered" rocks which typically occur in long, narrow, northeast-trending belts separated by a variety of younger plutonic rocks (Figure 2). The latter range in composition from gabbro or diorite to granite. The layered rocks have been folded into broad northeast-trending synforms and faulted antiforms. Major strike faults trend in the same direction. Regional metamorphism increases from greenschist facies in the southwest to amphibolite facies in the northeast. A few small outcrops of undeformed Tertiary sedimentary rocks occur in the south of the area.

According to published USGS 1:100,000-scale geological map, the Precambrian layered rocks of the region belong variously to the Baish, Bahah, Jiddah and Ablah groups, although the assignment of particular lithologies to these stratigraphic divisions is not consistent across the USGS map boundaries. In this report, the use of formal USGS stratigraphic terminology is avoided, as far as possible, but where that terminology is used, it refers to the correlations adopted by Hadley and Fleck (1979a,b).

Radiometric age dating has disclosed a wide range of ages within the layered rocks, from 1,165 ± 110 Ma in metabasalt of the Baish group, to 595 ± 11 Ma in kyanite schist of the Ablah group. The reliability of these ages is very doubtful (C. Hedge, pers. comm.).

2.3 PRECAMBRIAN LAYERED ROCKS

2.3.1 INTRODUCTION

The layered metavolcanic and metasedimentary rocks of the area are poorly described in the published literature. The 1:100,000-scale maps and accompanying explanations are very generalized, do not identify individual lithologies and, as such, do not form a suitable basis for mineral exploration. For the present investigation, it proved necessary to supplement these maps by photogeological interpretation and detailed geological mapping along selected traverses. The results of this mapping have been compiled onto a 1:100,000-scale map of the Wadi al Lith - Wadi Salibah area (Plate 1) and a 1:50,000-scale map of the Jabal 'Afaf area (Plate 2). The following abbreviated description of the layered rocks is based on internal Riofinex reports by Bavin (1983) and Grootenboer (1985).

2.3.2 ROCK TYPES

A limited number of rock types were found to be present throughout all the belts of layered rocks (Plates 1 and 2).

<u>Andesite flow rocks</u>: These include metavolcanic flow rocks of andesitic (and rarely basaltic) composition with subordinate interbedded volcaniclastic or pyroclastic rocks of similar composition. All rocks are of a general dark grey, greenish grey, and green colour and characterized by the presence of abundant chlorite and epidote. The flows make up approximately 70% of the sequence, are dense, fine- to medium-grained, commonly

porphyritic, and occasionally amygdaloidal. Individual flows range from 2 to 10 metres in thickness. Volcaniclastic beds, a minor part of the sequence, include agglomerate, various types of tuff, thin units of pyritic chert and occasional thin black shales.

Andesitic flow rocks are extensively developed in two areas to the east and west of the village of Ghumayqah respectively. Here, the rocks are generally massive, relatively undeformed, and show shallow to moderate dips. Schistose rocks of similar lithologic composition also occur within the linear belts of schistose metavolcanic and metasedimentary rocks (e.g. east of Wadi Hariq al Bi'r). The schistose andesites are interpreted as being the equivalents of the massive andesites, but having undergone more intense tectonic deformation.

Mafic volcaniclastic schists: These comprise lithic, crystal and ashfall tuffs of mafic composition with interbedded volcanic breccias, agglomerates and minor flow rocks. Agglomerate boulders generally measure less than 20 cm in diameter but measure up to 1 metre in the southwest of the investigation area. The mafic schists generally occur in close association with the andesitic flows described above. Individual units are from 10 cm to 2 m thick. The rocks are various shades of dark green and grey/black and are characterized by the widespread presence of chlorite/epidote. They are strongly sheared and almost invariably schistose, except in areas of higher-grade metamorphism where the rocks may be dense and massive. Internal stratification and original textural features have almost invariably been obliterated by shearing. Mafic volcaniclastic schists are common throughout all belts of layered rocks, though agglomerates are rare in the east.

Intermediate volcaniclastic schists: Highly schistose rocks of intermediate composition occur in all the belts of layered rocks, and frequently constitute the most common rock type. Massive and well-bedded crystal and lithic tuffs, generally of a buff, grey, or light green colour, are characterized by quartz-chlorite (±sericite) mineral assemblages. The coarser lithic tuffs have a characteristic patchwork appearance due to the flattening of fragments in the cleavage plane. Individual tuff horizons are seldom more than a few metres thick and often show detailed millimeter-scale layering. The schists are characteristically interbedded with more mafic and more siliceous tuffs. Interbedded conglomerates, cherty tuffs and thin andesitic lavas are present. The intermediate schists (and the interbedded cherty tuffs in particular) are frequently rich in pyrite but massive ironstones are not developed. The schists are very finely bedded in the east where they closely resemble sedimentary rocks but become coarser towards the southwest where lithic tuffs are common.

Siliceous volcaniclastic schists: These schistose rocks are characterized by quartz-sericite (±feldspar) mineral assemblages. The schists represent lithic and crystal tuffs and occasionally flow rocks. Though normally light-coloured to white on outcrop, the siliceous schists are frequently stained pink or red, due to their characteristic high-pyrite content. These rocks occur in close association with schists of intermediate composition, frequently taking the form of thin interbedded units. In a few localized areas, thick assemblages (up to 500 m thick) are developed. Rhyolite flows appear to be rare but they are frequently strongly sheared and cannot be distinguished from the finer-grained varieties of tuff in hand specimen.

Complex assemblages of rhyolitic rocks occur within the siliceous schists at several places. Coarse rhyolitic agglomerates and breccias (with clasts up to several metres in diameter) occur complexly interbedded with rhyolite flows, tuffs, dykes and sills. These rhyolitic assemblages are interpreted as representing volcanic complexes which served as feeders for the overlying siliceous tuffs.

Metasedimentary schists: Schistose metasedimentaty rocks are present in all schist belts throughout the investigation area but are best developed in the east. They are characterized by the presence of fine bedding and the frequent preservation of sedimentary features. A large variety of metasedimentary schists are present, ranging in composition from siliceous cherts and quartzites to magnetite-chlorite schists and garnet-bearing amphibolites. The presence of thin bands of marble is characteristic of virtually all metasedimentary stratigraphic sequences. Ferruginous quartzites are a characteristic of the Jabal 'Afaf area and were not found elsewhere. The metasedimentary rocks frequently show a relatively high (amphibolite facies) grade of metamorphism and characteristic minerals include hornblende, magnetite, garnet, kyanite and muscovite.

In a few small areas, relatively undeformed metasedimentary rocks occur outside the well defined schist belts. These rocks are often flat-lying and show gentle warping. They show close lithological similarity to schistose metasedimentary rocks occurring within the belts and are inferred to be their exact equivalents.

2.4 INTRUSIVE ROCKS

Precambrian plutonic rocks make up some 60% of the area. They show a broad range of compositions, from older mafic rocks (several varieties of gabbro and diorite) to younger granitic varieties, including granodiorite, quartz monzonite, and granite. The intrusive rocks appear to have little mineral potential and received only casual attention during the present investigation.

The petrology of the intrusive rocks is well described in the explanations accompanying the published 1:100,000-scale geological maps. There are, however, considerable discrepancies in the subdivision and correlation of the various suites of igneous rocks between individual map sheets (Cater, 1977; Hadley and Fleck, 1980a,b; Wier and Hadley, 1975).

Observations made during the present investigation suggest the presence of three major suites of intrusive rocks:

a) An older "Diorite Complex" in the west,
b) A "Granite Complex" of intermediate age in the east, and
c) Several young plutons distributed throughout both complexes.

This classification represents a simplification of that suggested by Hadley and Fleck (1980a,b) for the Al Lith and Jabal 'Afaf quadrangles.

2.4.1 DIORITE COMPLEX

A complex area of intrusive rocks of overall dioritic composition with numerous remnants of metavolcanic rocks, underlies most of the west and northwest of the Wadi al Lith - Wadi Salibah area. The great variety of rocks includes gabbro, granodiorite, quartz diorite, diorite, quartz monzonite, granite and aplite. The various intrusive rocks commonly grade into each other and are frequently intermixed. The majority of the rocks are foliated and often show a gneissic fabric; they appear to have undergone considerable tectonic deformation.

The variety of rock types and the geological complexity of this terrain is illustrated by the fact that the three published maps covering this area all used different classifications and show little or no continuity across their mutual boundaries.

2.4.2 GRANITE COMPLEX

An area of complex granitic terrain underlies the eastern half of the area. Much of this area is made up of a single large batholith of biotite-rich granodiorite and granite, but various other smaller plutons consist of tonalite and quartz monzonite. The rocks are frequently foliated and gneissic and generally appear to be syntectonic.

2.4.3 YOUNG PLUTONS

Several plutons of relatively younger age occur throughout the area. These include a variety of granites, quartz monzonite, quartz diorite, monzonite, quartz monzodiorite, gabbro, and granophyric granite. All these plutons are relatively homogeneous, have sharply defined boundaries, and appear to have undergone little or no tectonic deformation.

2.4.4 DYKES

Several sets of mafic and felsic dykes occur. The most prominent of these is a swarm of closely spaced, northeasterly trending dykes of mafic composition which follow the length of the central belt of schistose rocks (Hadley and Fleck, 1980a). They are composed of basalt, andesite and diabase and range in thickness from several centimetres to 2 metres and often can be traced for several hundreds of metres along strike. Elsewhere in the area, photogeological interpretation shows characteristic dyke swarms to be associated with individual younger plutons (Note: Most dykes have been omitted from Plate 1).

At many localities within the volcaniclastic rocks, dykes of granite, diorite and pyritic rhyolite are common, particularly near the contacts of these belts with the surrounding intrusive granites.

2.5 TERTIARY SEDIMENTARY ROCKS AND DYKES

Small outcrops of flat-lying clastic sedimentary rocks consisting of boulder conglomerate, pebble conglomerate, and sparse beds of coarse-grained sandstone outcrop in the south of the area. Detrital fragments represent a wide variety of Precambrian rock types. The rocks are commonly iron-rich and exhibit a deep red colour in roadcuts.

A prominent swarm of gabbro dykes extend across the area in a northwesterly direction. The dykes are generally parallel, but commonly bifurcate and occasionally crosscut. They range from 75 to 500 m wide. The contacts are fine-grained and resistant to weathering, but the centres are made up of coarse gabbro which is often readily weathered. The emplacement of these dykes is thought to be related to the opening of the Red Sea in Tertiary times.

2.6 METAMORPHISM

The layered rocks are regionally metamorphosed to the greenschist facies and in broad areas in the north and east to the amphibolite facies. Most of the plutonic rocks are similarly metamorphosed, except for the youngest post-tectonic intrusions. Greenschist facies mineral assemblages include chlorite, actinolite, albite, sphene, epidote, and calcite. The amphibolite-facies mineral suites are hornblende, quartz, biotite, andesite, staurolite, kyanite, garnet, epidote, sphene and apatite (Hadley and Fleck, 1980a,b).

Contact metamorphic effects are common throughout the area. In the northeast, the widespread amphibolite facies metamorphism appears related to the emplacement of large granite plutons. Within individual schist belts, extensive recrystallization of the metavolcanic rocks occurs in the vicinity of smaller intrusive bodies of both granitic and dioritic composition.

2.7 STRUCTURE

The Wadi al Lith - Wadi Salibah area is characterized by the presence of a number of linear, northeast-trending belts of schistose volcanosedimentary rocks. Beds strike parallel or subparallel to the length of the schist belts and dip at moderate to steep angles, generally to the west. While isoclinal folding has been inferred by previous workers, there is little direct evidence. Small-scale folding is rarely observed, except in the metasedimentary rocks in the east, and in several areas rocks were found to be flat-lying. The lack of repetition of lithological units within individual schist belts further suggests an absence of isoclinal folding. Nevertheless, in certain areas clasts within some of the lithic tuffs show severe flattening. Many of the schist belts are bounded by major strike faults, while elsewhere, they are intruded by younger igneous rocks. Numerous strike faults appear to be present within the individual schist belts.

The area is interpreted to be made up of a series of alternating, northeast-trending synclines and anticlines. The former comprise relatively undeformed open structures, whereas the anticlines are complexly faulted and sheared (see section, Plate 1).

The belts of schistose rocks in the west and northwest of the area are interpreted as representing the cores of intensely faulted, northeast-trending, anticlinal structures. The intense schistosity and steep dip of both bedding and schistosity are ascribed to the effects of these faults.

In contrast to the highly schistose and steeply dipping rocks of the anticlines, the rocks within the intervening synclinal areas are massive and generally shallow-dipping (see section, Plate 1). The distinction between these two types of structural terrain is most evident where the same rock unit can be traced across the syncline/anticline boundary (e.g. the andesites on either side of Wadi Hariq al Bi'r). In most instances, such boundaries appear to take the form of steeply dipping strike faults.

The extensive presence of surficial cover in the southeast of the Wadi al Lith - Wadi Salibah area makes it impossible to verify whether a similar alternation of faulted anticlines and undeformed synclines is again present. Evidence supporting this view is afforded by the flat-lying andesites and mafic sediments north and south of Wadi al Fajj, as well as the flat-lying metasedimentary rocks northeast of Jabal Bijalah. If this view is adopted, then the intrusive monzonites which occur west of Ghumayqah have been emplaced within a faulted anticlinal zone. In an alternative interpretation, the schistose rocks of the southeast could merely represent a westerly dipping stratigraphic sequence which has been duplicated by strike-faulting.

The Jabal 'Afaf area appears to represent the remnant of another simple, open anticline surrounded by younger intrusive rocks.

Northwest-trending faults are common in the southern half of the area. They displace the schist belts and appear to postdate the majority of the anticlinal strike faults. Many show considerable displacement. Within and to the west of the schistose rocks near Wadi al Faqh, these faults, though still present, appear to have a much smaller displacement. This suggests a late period of strike-faulting along the southeastern boundary of this belt.

2.8 REGIONAL STRATIGRAPHY

Previous workers have grouped the volcanosedimentary rocks of the area into "Older medium- to high-grade rocks", Baish group, Jiddah group, Bahah group and Ablah group. Such classifications are based on lithologic and structural similarities with rocks developed elsewhere in the southern Shield, rather than on relationship observed within the area under consideration. There are considerable discrepancies in stratigraphic correlations between the four 1:100,000-scale geological maps which cover the area.

In the course of the present investigation, little attention was paid to problems of stratigraphic correlation. However, field observations showed that throughout the entire area examined, broadly similar lithologies are present. It seems possible that all the metavolcanic and metasedimentary rocks are more or less cogenetic: observed variations in lithological composition, degree of deformation, and metamorphic grade being a reflection of facies changes, the effects of contact metamorphism and degree of deformation, rather than differences in geologic age.

The layered rocks of the various schist belts exhibit a regional facies change: from predominantly sedimentary in the northeast (and Jabal 'Afaf), through a mixed sediment/crystal tuff facies, to one dominated by lithic tuffs in the southwest. The possibility of apparent differences in age between steeply dipping, schistose and massive, flat-lying rocks merely being the result of varying degrees of structural deformation, has already been discussed (Section 2.6). Amphibolite facies metamorphism is only developed in the vicinity of the intrusive rocks of the "granite complex" and, as such, probably reflects large-scale contact metamorphism rather than an inferred older period of regional metamorphism.

3 EXPLORATION

3.1 PROGRAM FOLLOWED

Work was carried out over several field seasons under various sub-programs:

1400-1401

Sub-program 3.01.16 (Regional Assessment - Wadi al Lith - Wadi Salibah) - Desk studies comprised a review of all published data pertaining to the geology and mineralization of the investigation area. Interpretation of Landsat imagery and aerial photography (Sections 3.2, 3.3).

1401-1402

Sub-program 3.01.16 - Regional geological reconnaissance in the Wadi al Lith - Wadi Salibah area over a two-month period from Jumad Awal to Rajab 1402 (March to May, 1982). Work involved geological mapping, prospecting, rock-chip and drainage geochemistry along selected foot traverses (Sections 3.4, 3.5).

1402-1403

Sub-program 3.11.63 (Shield Layered Formations, Prospecting Wadi al Lith - Wadi Salibah) - Prospect-scale investigations over several of the mineral occurrences found during 1401-1402 (Section 6). Work involved detailed geological mapping and systematic sampling. Drainage geochemistry surveys were carried out over five selected areas (Section 4). A regional gravity profile was measured (Section 5).

Sub-program 3.01.42 (Regional Assessment - Jabal 'Afaf) - During 1401-1402, samples of ferruginous quartzites in Jabal 'Afaf area had been found to carry low gold values. A geological reconnaissance program aimed at evaluating the mineral potential of the Wadi 'Afaf area in general, and the gold potential of the quartzites in particular, was carried out during 1402-1403.

3.2 PHOTOGEOLOGICAL INTERPRETATION

Prior to field work, a photogeological interpretation of the Wadi al Lith - Wadi Salibah area was undertaken to obtain more detailed geological information on the layered rocks than was available from published 1:100,000-scale maps. In particular, the full extent of the belts of schistose metavolcanic and metasedimentary rocks was outlined and areas of siliceous schist identified. Structural information which might have a bearing on the localization of mineralization was identified. In a general context, the photogeological interpretation was aimed at providing a fuller understanding of the regional geology of the area and the geological setting of mineralization present.

Interpretation was carried out on 1:60,000-scale contact prints of the SAG series of photographs. Interpretation was traced onto transparent overlays to the photographs and then transferred onto a base map using an optical pantograph and a series of fixed control points. The base map was derived from existing 1:50,000-scale photomosaics of the area. These mosaics are uncontrolled and occasionally inaccurate, as can be seen from comparison of the major features with enlargements from Landsat imagery. However, since the existing geological maps had also used similar bases, it was felt preferable to use these rather than Landsat imagery.

Results of the photogeological interpretation were compiled onto four separate 1:50,000-scale compilation maps. These were subsequently photographically reduced and compiled onto a single 1:100,000-scale map covering the entire area. (All this material is stored in the Data File RF-DF-01-04.) The photogeological map was used to identify the various geological environments present in the area and the location of proposed foot traverses.

3.3 LANDSAT INTERPRETATION

An initial interpretation was made of the 1:250,000-scale Landsat imagery available for the area. The results are stored in Data File RF-DF-01-04.

While major lithological and structural features can be identified from the imagery, it does not show the detail required for the present investigation. This is due to the lack of resolution of the imagery, the rugged topography of the area and resultant shadow effects, as well as the complex geology. It proved necessary to proceed to the detailed interpretation of 1:50,000-scale aerial photographs to obtain the necessary amount of geological information.

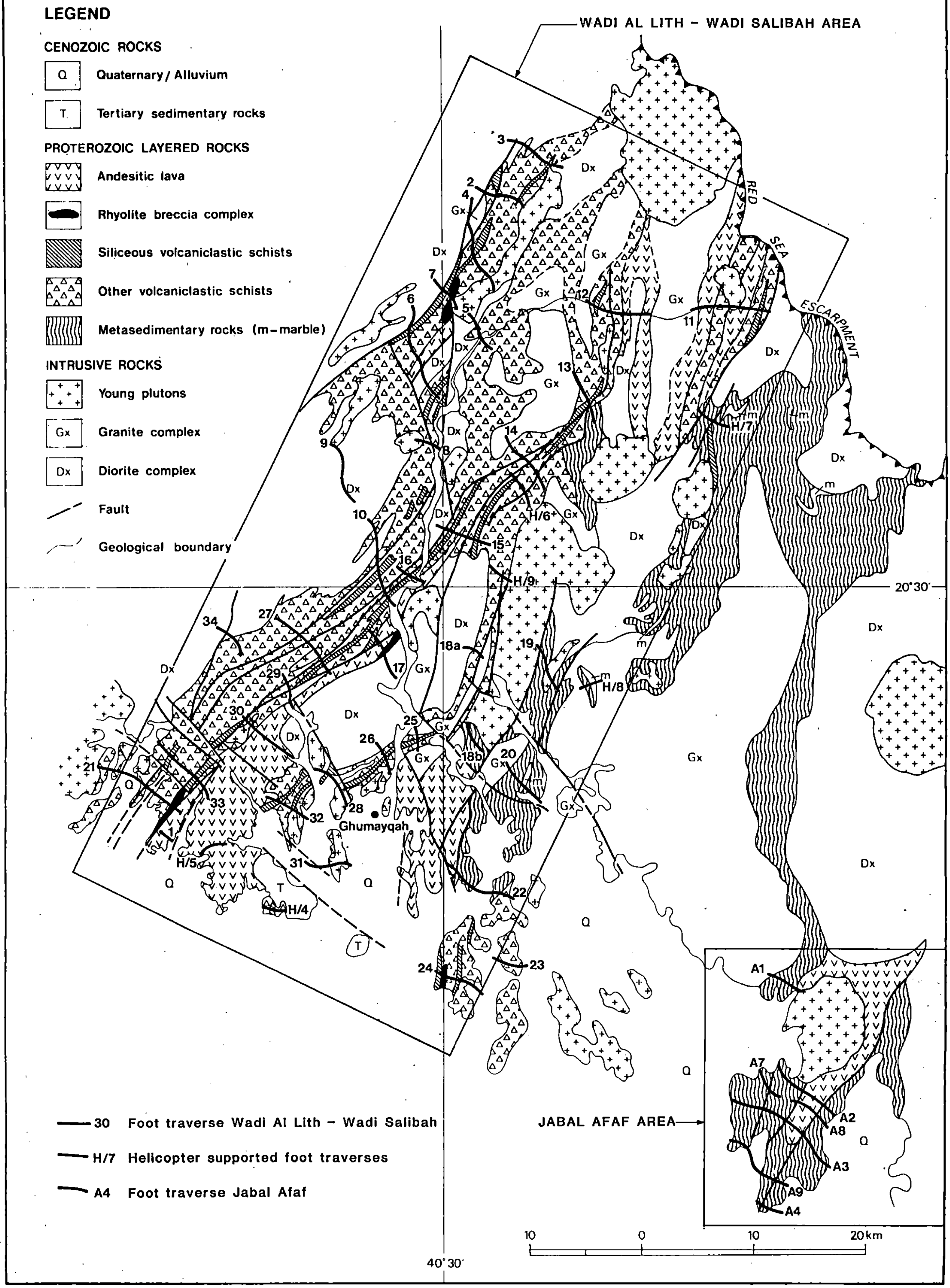
3.4 REGIONAL RECONNAISSANCE

An initial two-day visit was made to the investigation area during Safar 1402 to examine access and determine logistical requirements. During 1401-1402, systematic field investigations were carried out in the Wadi al Lith - Wadi Salibah area over a two-month period from Jumad Awal to Rajab 1402 (March to May, 1982). In the following field season, similar work was carried out at Jabal 'Afaf over a period of four days during Rabi Awal 1403.

The first phase of field work consisted of foot traverses across all the different geological environments present in the layered rocks as identified from photogeological interpretation, the results of previous Riofinex investigations and published geological maps. The objectives were to gain an understanding of the geological features of these environments, to assess their potential for mineral occurrences on the basis of known models of mineralization, and to locate directly any mineralization which may be present. While all geological environments present were examined, traversing concentrated on the siliceous metavolcanic rocks which were felt to hold the greatest potential for volcanogenic massive sulphide deposits.

A total of 34 foot traverses were carried out in the Wadi al Lith - Wadi Salibah area. Their location is shown in Figure 3. Detailed geological mapping conducted along these traverses forms the basis of the geological compilation map (Plate 1). A total of 1,094 rock-chip samples were collected of all potentially mineralized outcrops including altered and ferruginous metavolcanic and metasedimentary rocks, ironstones, quartz veins, etc. (Section 3.5.1). The majority of traverses were conducted up

WADI AL LITH - WADI SALIBAH AND JABAL AFAF LOCATION OF TRAVERSES



wadis and these, together with all side wadis, were prospected for boulders of ironstone and any other mineralized rock. Where found, such boulders were traced to their source. Wadi-sediment samples were collected from 381 sites during foot traversing.

Further geological reconnaissance was carried out with helicopter support. Helicopter "drops and pick-ups" were used to carry out foot traverses in otherwise inaccessible areas. The helicopter was also used to prospect the strike extensions of lithological units which had been found to host mineralization. Rock-chip sampling of all prospective outcrops and a limited amount of wadi-sediment sampling was again carried out.

Detailed geological mapping was carried out along all foot traverses. Results were transfered onto 1:50,000-scale photogeological base maps (stored in Data File RF-DF-01-04). These were subsequently reduced to 1:100,000 scale, and a simplified geological reconnaissance geological map at this scale compiled (Plate 1). The location of the traverses and field stations on which this map is based are clearly indicated, so as to allow clear recognition of the limited amount and non-uniform distribution of the field data, as well as the distinction between fact and interpretation.

A similar program of geological traversing was followed in the Jabal 'Afaf area, where nine traverses were completed during 1402-1403 (Figure 5).

3.5 GEOCHEMICAL RECONNAISSANCE

In the course of geological traversing, a large number of rock-chip and wadi-sediment samples were collected. This geochemical sampling was undertaken to identify mineralized outcrops and to provide geochemical "fingerprints" of the various geological environments present in the area. Results are stored in Data File RF-DF-01-04. A brief summary of the results is given in subsequent sections.

3.5.1 ROCK-CHIP GEOCHEMISTRY

A total of 1,135 rock-chip samples were collected from ferruginous and sulphide-bearing outcrops, ironstones and quartz veins. At each outcrop, several selected grab samples were collected and assayed for copper, lead, zinc, nickel, cobalt, silver and gold. In addition, samples of quartz veins, granite, and some metasedimentary rocks were also analysed for tin and tungsten. No systematic statistical analysis of the data was undertaken, but the upper 5% of the assay values for any particular element was taken as being geochemically anomalous. The thresholds determined in this manner (Cu 800 ppm, Pb 100 ppm, Zn 550 ppm, Ni 400 ppm, Co 200 ppm, Ag 5 ppm and Au 0.1 ppm) are in close agreement with Riofinex experience in comparable areas of the Saudi Arabian Shield.

Anomalous assay results (primarily Cu and Zn) were returned from 34 mineralized outcrops as well as from 18 localities where gossan boulders were found in wadis (the more important results are summarized in Table 1 and Figure 4). An additional 30 outcrops of ironstone were found to be barren of metal values. The majority of the mineralized outcrops represent ironstones, but sulphide-rich siliceous tuffs, rhyolitic cherts, malachite-bearing metavolcanic rocks and occasional quartz veins are also present. A few of the ironstone samples contain anomalous Ni and Co values, but elevated Pb values are rare and only one sample contains precious-metal values.

Only five samples returned Au values above the analytical threshold of 0.1 ppm.; two quartz veins, a gossan, a rhyolitic chert, and a ferrugionous quartzite. None of the approximately 500 samples of quartz, granite or metasedimentary rock assayed for Sn or W showed elevated values. Selected samples of malachite-stained metavolcanic rocks yielded spectacular copper values.

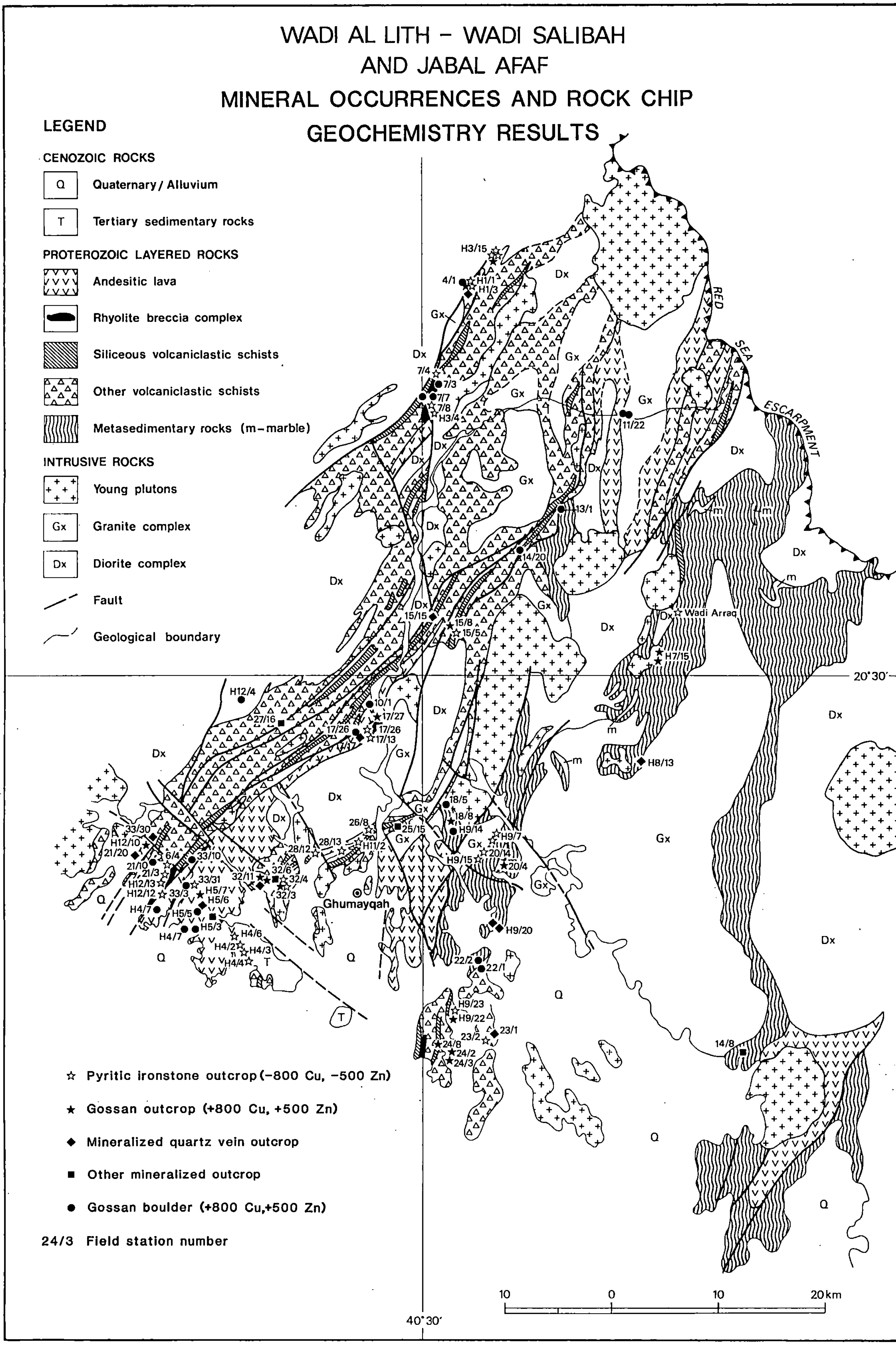
The majority of the mineralized outcrops are of very small size and the mineralization clearly is not of any exploration significance. The more significant mineral occurrences are discussed more fully in section 6.

TABLE 1

MINERAL OCCURRENCES YIELDING SIGNIFICANT ASSAY RESULTS
Wadi al Lith - Wadi Salibah Area

Location	No. of Samples	Assay Values (in ppm)							Surface Dimensions	Description
		Cu	Pb	Zn	Ni	Co	Ag	Au		
1/12	1	92000								Stream boulder of Cu-stained andesite
7/3	1	11600			950					Stream boulders - ironstones
7/7,10	3	2000-4500			35-650					Stream boulders - ironstones
10/A	4	3300-62000		299-600					+20 m x 2 m	O/C - ironstones along contacts of mafic dyke in andesite
11/22	2	430-2430	10-200			20-1550	3.2-19.6	5-54		Stream boulders - mineralized vein quartz
15/15	2	340-2160							20% of 5 m thick fm.	O/C stratabound quartz veins in felsic tuffs
17/16,17	5	8-3520				60-740	-2.0	0.8-10.6	100 m x 1 m	O/C - quartz vein with ironstone in basalt
17/27	5	150-1260			110-1250				20 m x 1 m	O/C - crosscutting ironstone in andesite
18/8	6			200-540						O/C - stratiform ironstone pods in black shale/amphibole
21/10	4	1130-2310			1600-11000	180-1350				Stream boulders - ironstone
24/2	5			20-7750					30 m x 0.5 m	O/C - stratiform ironstone
24/3	5		-60	1100-5350					30 m x 2 m	O/C - stratiform ironstone
25/1	2	38-1200	-50	20-2850			-12	-36	10% of 5 m thick fm?	O/C - pyritic felsic tuff formation
27/16	4	1680-142000	80-450	650-7300					+20 m x 0.5 m	O/C - sheared stratiform Cu-stained rhyolite in dacite
32/6	3	5000-5500							+100 m x 0.5 m	O/C - Cu-stained cherty rhyolite
32/10A	3	1940-6300	35-2000	340-875			-6.8		-100 m x 0.3 m	O/C - ironstone in felsic tuffs
32/10B	3	4120-10400		135-650					+50 m x 0.2 m	O/C - ironstone in andesitic tuffs
33/10	1	62600								Stream boulder - Cu-stained andesite
33/30	2	1920-2800	30-110						10 m x 3 m	O/C - ironstone pod in quartz vein
H1/1	3	118-2800						-5.0	10 m x 1 m	O/C - ironstone in shear zone in diorite
H3/15	4	580-850							10% of 10 m thick fm.	O/C - ironstone in felsic tuffs
H4/9	9	356-58000	-895	45-3350			1.0-9.2		2 lenses 100 m x 2 m	O/C - crosscutting ironstones in andesitic volcanics
H5/3	1	1240				3200				Stream boulder - ironstone
H5/6	4	18-1460			-800		-3.8		10 m x 2 m	O/C - mineralized quartz vein
H7/15	7	1180-4220							3 lenses 30 m x 5 m	O/C - ironstones in amphibolite
H8/13	3		150-1450				-2.8		20 m x 2 m	O/C - quartz vein in granite
H9/20	3	84-4980	-2800	-1900					20 % ov 5 m thick fm.	O/C - stratabound quartz veins in felsic tuffs

FIGURE 4


WADI AL LITH - WADI SALIBAH
AND JABAL AFAF
MINERAL OCCURRENCES AND ROCK CHIP
GEOCHEMISTRY RESULTS
LEGEND
CENOZOIC ROCKS
Q Quaternary / Alluvium
T Tertiary sedimentary rocks
PROTEROZOIC LAYERED ROCKS
Andesitic lava
Rhyolite breccia complex
Siliceous volcaniclastic schists
Other volcaniclastic schists
Metasedimentary rocks (m-marble)
INTRUSIVE ROCKS
Young plutons
Gx Granite complex
Dx Diorite complex
Fault
Geological boundary
☆ Pyritic ironstone outcrop (-800 Cu, -500 Zn)
★ Gossan outcrop (+800 Cu, +500 Zn)
◆ Mineralized quartz vein outcrop
■ Other mineralized outcrop
● Gossan boulder (+800 Cu, +500 Zn)
24/3 Field station number
RED SEA ESCARPMENT
Wadi Arraq
Ghumayqah
20°30′
40°30′
10 0 10 20km

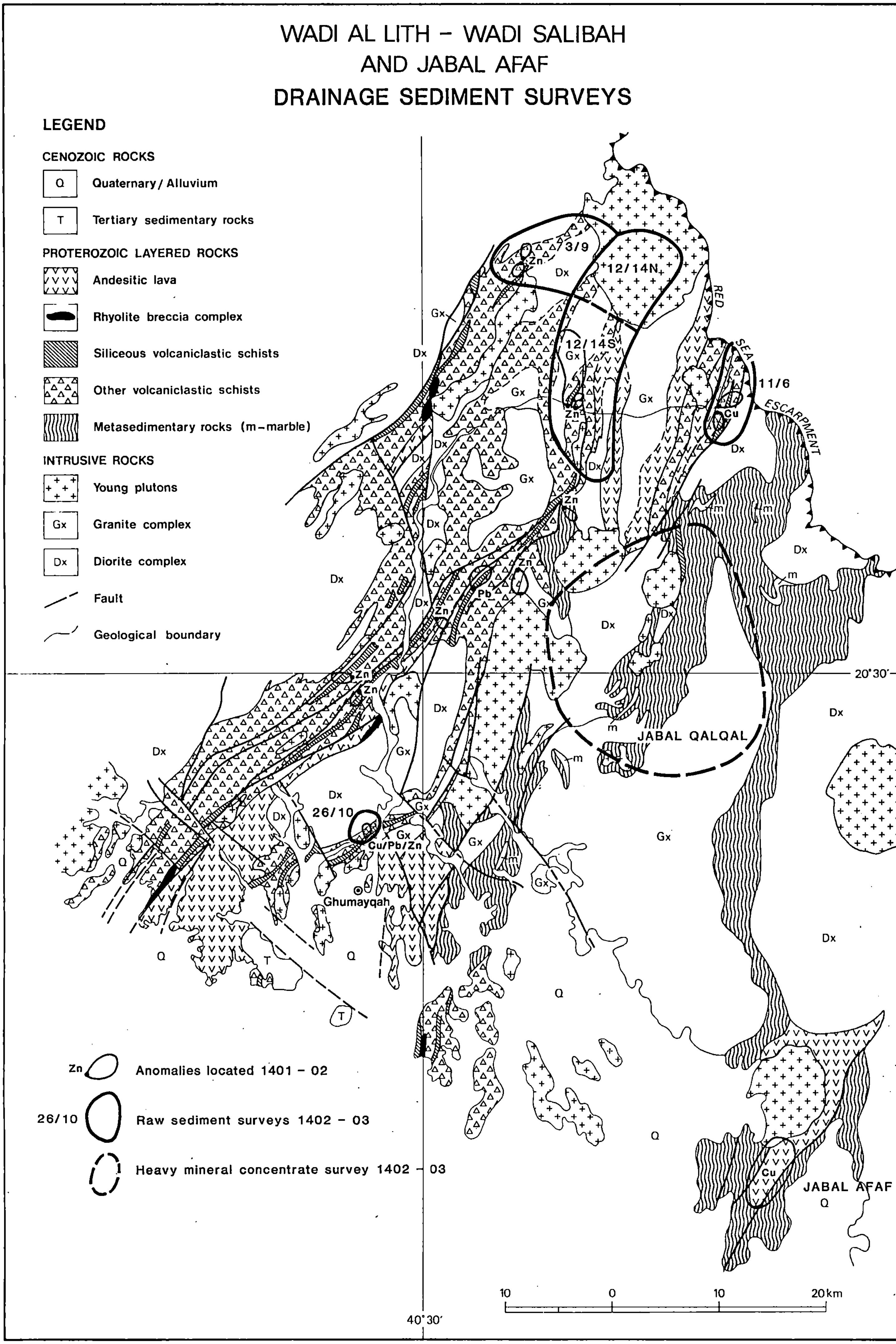
3.5.2 WADI-SEDIMENT GEOCHEMISTRY

A total of 890 wadi-sediment samples were collected at 445 sites from wadis encountered along the traverses. A limited number of additional samples were collected from the vicinity of mineralized outcrops, using a helicopter. Samples were of raw sediment and two size fractions (-1mm +20 mesh, and -20, +40 mesh) were sieved-out on site. Samples were collected across the full width of the wadi in active channels. All samples were analyzed for Cu, Pb, Zn, Ni, Co, Mo, and As. In general, little or no difference was found between the results of the two size fractions and interpretation was carried out on both size fractions. Anomalous thresholds for each element were estimated at mean plus two standard deviations.

No major geochemical anomalies were found but assay results outlined five areas of elevated geochemical values (Figure 5). Two areas show values >150 ppm Zn, two areas (including Jabal 'Afaf) >100 ppm Cu, while a further area is anomalous in all three metals - Cu, Pb, and Zn. No anomalous As and Mo values were found in any of the samples.

One copper anomaly is located in the Jabal 'Afaf area and clearly relates to the presence of andesitic metavolcanic rocks rather than indicating the presence of mineralization. The same applies to a number of elevated zinc values, in the Wadi al Lith - Wadi Salibah area, which occur in wadis draining black shales and siltstones.

Further systematic wadi-sediment geochemistry surveys were conducted over four areas during 1402-1403. These are described in the next section.


WADI AL LITH - WADI SALIBAH
AND JABAL AFAF
DRAINAGE SEDIMENT SURVEYS
LEGEND
CENOZOIC ROCKS
Q Quaternary / Alluvium
T Tertiary sedimentary rocks
PROTEROZOIC LAYERED ROCKS
Andesitic lava
Rhyolite breccia complex
Siliceous volcaniclastic schists
Other volcaniclastic schists
Metasedimentary rocks (m-marble)
INTRUSIVE ROCKS
Young plutons
Gx Granite complex
Dx Diorite complex
Fault
Geological boundary
Zn Anomalies located 1401 - 02
26/10 Raw sediment surveys 1402 - 03
Heavy mineral concentrate survey 1402 - 03
3/9
12/14N
12/14S
11/6
26/10
Cu/Pb/Zn
Ghumayqah
JABAL QALQAL
JABAL AFAF
RED SEA ESCARPMENT
20°30'
40°30'
10 0 10 20km

4 WADI-SEDIMENT GEOCHEMISTRY SURVEYS

4.1 PROGRAM OUTLINE

The non-systematic wadi-sediment sampling undertaken during 1401-1402 (Section 3.5.2) had outlined four areas of elevated base-metal values in the Wadi al Lith - Wadi Salibah area (Figure 5):

Area 3/9 - zinc
Area 11/6 - copper
Area 12/14 - zinc
Area 26/10 - copper, lead, zinc

During 1402-1403, systematic wadi-sediment geochemistry surveys were conducted over all four areas. The survey covering area 12/14 was extended further north to include a copper anomaly (in the magnetic fraction of panned concentrates) located recently by the USGS (du Bray and Doebrich, 1981). In addition, a heavy-mineral concentrate survey was carried out over the Jabal Qalqal area where young granitic plutons intrude carbonate-rich metasedimentary rocks, a geological environment potentially favourable for tin, tungsten, rare earth and uranium/thorium mineralization.

Only a brief description of these surveys is included in the present report. A full description is found in an internal Riofinex report (Bavin, 1983b), stored in Data File RF-BD-01-04.

4.2 PROCEDURES

4.2.1 WADI-SEDIMENT SURVEYS

Sample collection was carried out with helicopter support in most areas. A sampling density of 3-4 samples per square kilometre was aimed at, but proved impossible to achieve in the more rugged areas. Composite samples of approximately 1 kg each were collected from active channels across the entire width of the wadi. The majority of wadis sampled had immature profiles and were less than 3 m wide, where sampled. After drying, the <2mm - >450 micron fraction was sieved from the bulk sample and 250 grams of this was crushed for multi-element analysis (Cu, Pb, Zn, Ni, Co, Fe, Mn, Ag, Au, As).

4.2.2 HEAVY-MINERAL CONCENTRATE SURVEY

Sample collection was again carried out with helicopter support. Sixty-three samples of 10 kg each were collected from an area of 330 km^2. After drying, all samples were screened to <1 mm. Samples were then split into two size fractions (<1 mm - >600 micron, and <600 - >300 micron) and 150 grams of each fraction retained for multielement analysis (Cu, Pb, Zn, Ag, Au, Sn, W, La, Ce, Y, Nb, CaF_2, Ta, and Th). Five hundred grams of the <600 - >300 micron fraction were concentrated using a Goldhound. Cassiterite and scheelite grain counts and multi-element analysis (Cu, Pb, Zn, Ag, Au, Sn, W, La, Ce, Y, Nb, CaF_2, Ta, and Th) were performed on the non-magnetic fraction of these concentrates.

Grain counts revealed two scheelite and one powellite anomaly and a further 35 follow-up samples were collected from the anomalous areas and processed as before.

4.3 RESULTS

A detailed description of the results of these geochemical surveys is given in Bavin (1983). They are briefly summarized below.

4.3.1 AREA 3/9

Fifty-one samples were collected from an area measuring 55 km^2. The original small zinc anomaly is reconfirmed but no other anomalous values are present. The peak value of 260 ppm Zn may be due to scavenging by manganese.

4.3.2 AREA 11/6

Only twenty-two samples could be collected from an area of 35 km^2 in extremely rugged terrain. No geochemical anomalies were detected and the original anomalous copper values were not repeated.

4.3.3 AREA 12/14

From an area measuring 100 km^2 and representing the southern half of Area 12/14 (Figure 5), 89 samples were collected. No major anomalies are present but some samples have elevated copper, zinc, and nickel values. These values are isolated and do not appear to warrant follow-up.

Low-density sampling (29 samples from 100 km^2) was carried out over the northern half of this area to confirm the inferred potential for porphyry copper mineralization (du Bray and Doebrich, 1981). No anomalous Cu values were returned by any of the samples. It can only be inferred that the Cu content of magnetite from a granite pluton is no indicator of the presence of porphyry copper mineralization.

4.3.4. AREA 26/10

Forty samples were collected from an area measuring approximately 15 km^2 underlain by siliceous and intermediate volcaniclastic schists. The original Cu/Pb/Zn anomalies detected during 1401 were repeated and a concentration of similar anomalies was identified. A further 23 follow-up samples were subsequently collected from this anomalous area, which measures 0.4 km^2. The results outline a distinct geochemical Cu/Pb/Zn anomaly which trends parallel to the strike of the volcaniclastic schists. Detailed geological traversing and rock-chip sampling, however, failed to identify a source for the geochemical anomaly.

4.3.5 JABAL QALQAL AREA

A heavy-mineral concentrate survey encompassed an area of approximately 330 km^2 from which 63 bulk samples were collected. Assay results on raw wadi-sediment samples showed no anomalous base-metal contents, though zinc values were found to show a bi-modal distribution, the higher values occurring over areas underlain by rocks of the "Diorite Complex".

Grain counts on nonmagnetic heavy-mineral concentrates identified one powellite and two scheelite anomalies. Elevated W assay values support the scheelite anomalies. The anomalies all occur in wadis draining the Jabal Qalqal monzogranite pluton. Several samples also show anomalous Nb, Ce, Y, Ta and Th values.

Further follow-up sampling was undertaken over the anomalous areas and another 35 samples collected. Budget restraints prevented these samples from being sent for overseas XRF analysis. Heavy-mineral grain counts duplicated the earlier scheelite and powellite anomalies, but a Riofinex program of regional evaluation of scheelite mineralization in the At Ta'if - Bahah area (Gaukroger, 1985) showed the anomalies to be insignificant in relation to results from other areas. Geological examination of the anomalous area identified small wolframite-bearing pegmatite sills as the probable cause for the anomalies.

4.4 CONCLUSIONS

Wadi-sediment geochemical surveys of relatively low sample density failed to identify significant anomalies in areas 3/9, 11/6, or 12/14. No copper anomaly indicative of the presence of porphyry copper mineralization was found in the latter area. No further investigation of these areas is warranted.

The source of a persistent, stratiform Cu/Pb/Zn anomaly in area 26/10 could not be identified. Further work in this area and its strike extensions is warranted on a low-priority basis.

The scheelite, powellite and tungsten anomalies in the Jabal Qalqal area result from mineralization of no economic significance. The significance of several Nb, Ce, Y, Ta and Th anomalies still remains to be investigated.

5 GEOPHYSICS

5.1 REGIONAL GRAVITY PROFILE

A 50-km-long gravity profile was surveyed to help in understanding the regional structure of the Wadi al Lith - Wadi Salibah area. Readings were taken at intervals of 100 metres along a single line across the relatively flat southern portion of the area (Plate 1). A simultaneous magnetic profile was also measured. Details of this survey and the interpretation of the results are described in an internal Riofinex report (Harvey, 1985) stored in Data File RF-DF-01-04.

The interpreted geological cross-section presented on Plate 1 is consistent with the results of the gravity survey.

6 MINERALIZATION

6.1 INTRODUCTION

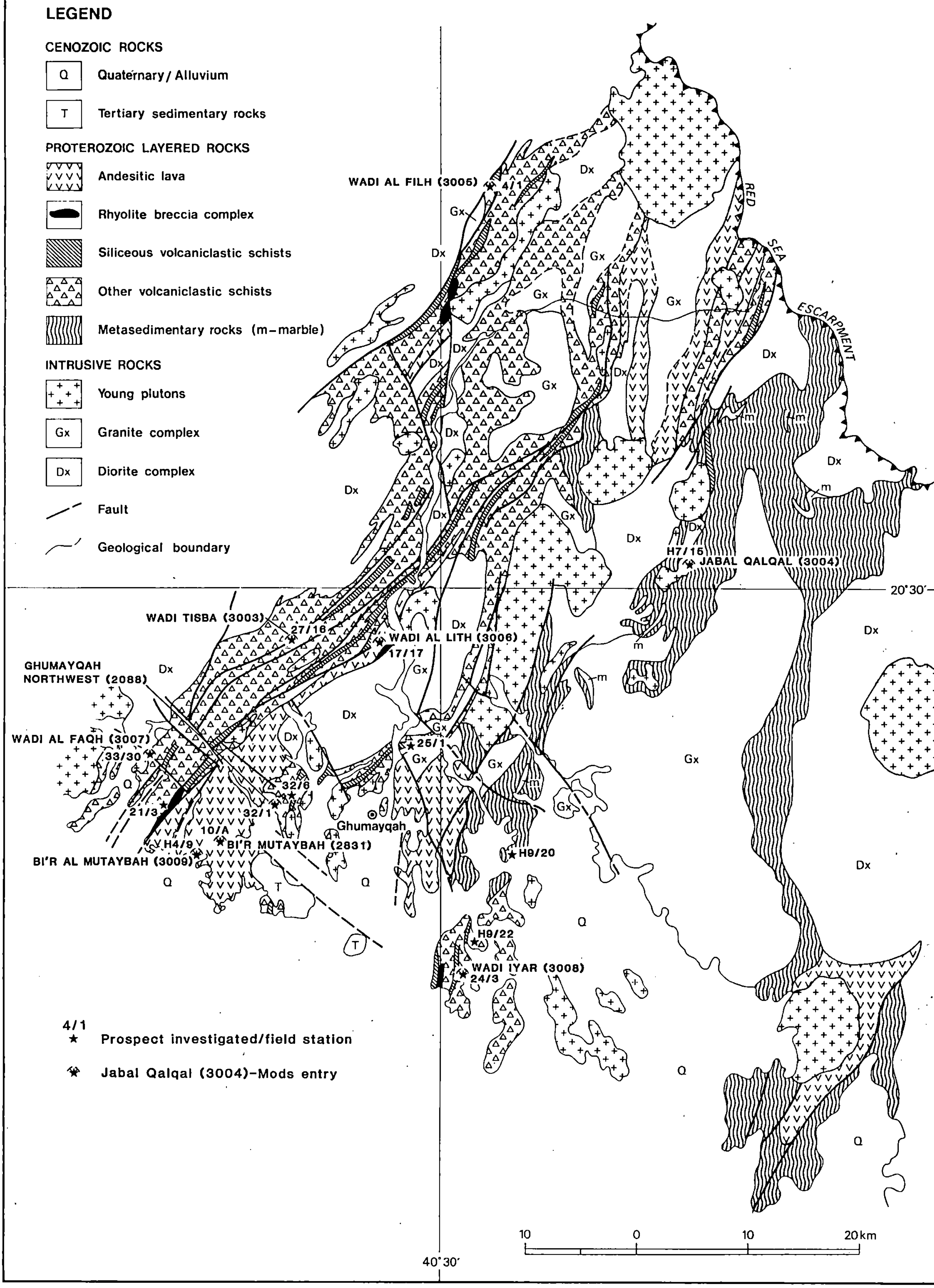
No ancient workings are present in the area investigated. In the course of 1:100,000-scale mapping of the Al Lith quadrangle (20/40C), three areas of base-metal mineralization were located (Hadley and Fleck, 1980a). These occurrences are small and carry insignificant metal values. One, Ghumayqah West (MODS 1139), probably represents a secondary surficial ironstone leached from Tertiary sedimentary rocks. Geological reconnaissance by Bowden and Morfett (1979) resulted in the identification of the Ghumayqah northwest (MODS 2088) and Wadi Arraq ironstones (Figure 6). The former is small and carries anomalous base metal and silver values; the latter is large but appears to represent a pyritic-ironstone without base-metal mineralization.

In the course of geological reconnaissance undertaken during 1401, samples from 34 mineralized outcrops were found to contain anomalous metal values. At a further 18 localities, mineralized boulders were found in wadis and the majority traced to their source. The mineralized outcrops occur in a variety of geological environments. Selected grab samples frequently yielded high assay values, but the majority of the occurrences were found to be of extremely small size.

Fifteen of the more significant of these occurrences were investigated more thoroughly during 1402 (Figure 6). Prospect-scale investigations included detailed (1:2,000-scale) mapping of the occurrences and their surroundings, systematic rock-chip and channel sampling, and physical prospecting for further mineralization in the vicinity of the occurrences.

A summary description of the mineralization encountered during the present investigation is given in subsequent sections. A fuller description (accompanied by geological maps of fifteen occurrences) is given in an internal Riofinex report (Bavin and Grootenboer, 1983) stored in Data File RF-DF-01-04.

WADI AL LITH - WADI SALIBAH AND JABAL AFAF PROSPECTS INVESTIGATED 1402 - 03



6.2 TYPES OF MINERALIZATION

Pyrite is abundant throughout the layered rocks of the area. This is particularly true of the more siliceous schists (their pink colour derives from the oxidation of pyrite) and certain types of black shale. Pyrite contents of 10% are common in these rocks and may occasionally reach 40%. Locally, lenses of stratiform submassive to massive ironstone are developed, the largest of which may be up to 20 metres thick and a hundred or more metres in length. These ironstones are almost invariably devoid of base- or precious-metal values. In areas of rugged topography, secondary transported ironstones, which have been leached from pyrite-rich siliceous schists, are relatively common.

Several ironstones carry anomalous base-metal values. These are invariably small and occur in a variety of host rocks. The western ironstones which occur in siliceous pyroclastic rocks generally contain only anomalous copper values, but the sediment-hosted ironstones in the east frequently carry copper and zinc values. The more siliceous schists often host miniature stratiform Cu and Cu/Zn-bearing ironstones, generally only a few tens of centimetres in thickness. Elsewhere, small cupriferous ironstones occur along faults and shear zones.

The mafic schists include horizons of thinly bedded metasedimentary rocks and black shales. These are commonly pyritic and have an elevated zinc content, but host no mineral occurrences.

Amphibolitic rocks contain numerous small stratiform ironstones with anomalous Cu and Zn contents.

The andesitic flow rocks are characterized by several small occurrences of high-grade copper mineralization, mostly shear-controlled. In the diorite complex, a few small copper-bearing ironstones (with scattered gold values) occur associated with rhyolitic dykes.

Quartz veins occur sparsely distributed throughout all rocks units. They carry no tin or tungsten values. It is extremely rare for these veins to contain any gold. Such values as do occur appear to be erratic and can not be repeated on resampling. Small pods of massive ironstone occur adjacent to some of the quartz veins and blows and occasionally carry elevated base metal values. Swarms of thin stratabound quartz-carbonate veins occur within some of the siliceous schists and in rare instances carry elevated Cu and highly erratic Au values.

6.3 MINERAL OCCURRENCES

6.3.1 SILICEOUS VOLCANICLASTIC ENVIRONMENT

Occurrence 32/10 (Ghumayqah northwest, MODS 2088) - This occurrence was first described by Bowden and Morfett (1979) who reported anomalous Cu, Pb, Ag, and Zn values. A small stratiform ironstone (<1 x 50 m) occurs at the contact of a rhyolite sill (flow?) and overlying siliceous tuffs. Grab samples show up to 6,300 ppm Cu, 200 ppm Pb, 875 ppm Zn, 68 ppm Ag.

One hundred metres to the west, a second smaller ironstone occurs within lithic tuffs of intermediate composition. Grab samples again show high Cu values (up to 1%). No extensions to the above mineralization were found in the vicinity.

Occurrences H3/15, 15/5, H9/22, 7/8, Wadi Arraq - Though virtually all the layered rocks of the areas investigated are ferruginous, the siliceous volcaniclastic rocks frequently contain up to 10% or more iron-oxides (after pyrite). At the above localities (Figure 4, Plate 1) the rocks are sufficiently pyrite-rich for bodies of semi-massive to massive stratiform ironstone to have formed. The ironstones frequently occur in clusters, are a few metres wide and up to 100 metres or more in length. The most common host rock is a siliceous crystal tuff, but some of the ironstones occur in microgranite, or in close association with massive rhyolite flows. Individual samples often contain up to 300 or 500 ppm Cu but the regular content is much lower and no other significant base- or precious-metal values are present. Though stratabound, the more prominent ironstones all occur in close proximity to small bodies of younger intrusive granite.

These ironstones are inferred to represent the oxidized outcrops of barren, massive pyritic iron formations.

Pyritic quartzite 26/9, H11/2, 28/12,13, 32/3,4 - A highly characteristic rusty weathering, iron-oxide-rich "quartzite" outcrops at all the above localities and appears to represent a single stratigraphic horizon which can be traced over a strike length of tens of kilometres. While a layered, quartz-limonite rock occurs at all localities, it occurs in association with a wide variety of siliceous metavolcanic rocks.

These include rhyolitic agglomerates, rhyolite flow rocks and siliceous and lithic tuffs. Apart from limonite, other characteristic minerals include muscovite and kyanite. The unit is from 3 to 15 metres in thickness and probably averages 10-20% pyrite. Locally, small massive ironstones are present. Extensive sampling shows the quartzite to have low base- and precious-metal values, except for copper which is slightly elevated and generally of the order of 20-200 ppm. A few rare high-copper values (max. 860 ppm) are also present.

Rhyolite complexes 7/1, 21/3, 17/26

Disseminated stockwork and massive iron-oxide (after pyrite) mineralization occurs associated with complex associations of rhyolitic rocks at several localities. The Wadi Joma complex (station 7/1, Plate 1) measures some 2,000 x 500 m and consists of rhyolitic tuffs, coarse breccias (clasts >1 m) and flows. All rock types are rich in disseminated iron-oxides, but locally, irregular zones of stockwork mineralization and massive ironstone are developed. Extensive sampling of these ironstones showed extremely low base- and precious-metal values.

A massive pyritic rhyolite sill with minor flow rocks and rhyolite breccia occurs within andesitic flow rocks, siliceous tuffs and rare black shales at Station 21/3. Both the rhyolite and the siliceous schists show varying degrees of iron-oxide enrichment and several ironstone lenses, up to 30 metres long and 1.5 m wide, are present. These again contain low base- and precious-metal values. Detailed (1:5,000-scale) geological mapping shows the ironstones to occur adjacent to massive quartz veins and to have been emplaced along fracture zones (Bavin and Grootenboer, 1984).

At Station 17/26 a complex assemblage of rhyolite flows and intrusive rocks show locally intense iron staining and the occasional presence of small ironstone lenses. Thirteen grab samples failed to show any metal enrichment and the mineralization is again assumed to represent barren pyrite.

Rhyolitic chert

Two small occurrences of rhyolitic chert were found, both of which are mineralized. These occur in a mixed assemblage of thinly bedded rocks ranging from mafic flows to siliceous tuffs.

At Station 25/1 a single grab sample from a small (10 x 100 m) lens of rusty, finely laminated chert assayed 38 ppm Au. This value could not be duplicated on resampling, the highest value from 20 samples being 1.2 ppm.

A thin (0.1-0.6m) malachite-stained, red-weathering, well-banded, volcano-sedimentary chert outcrops intermittently over 300 m at Station 32/6. Systematic channel sampling during 1403 showed values between 800-4400 ppm Cu. The occurrence is too small to be of economic interest.

6.3.2 ANDESITIC METAVOLCANIC ENVIRONMENT

Siliceous schists/black shales

Thin units of rusty siliceous schist which occur interbedded with black shales often show considerable enrichment in iron oxides (after disseminated pyrite) and the occasional presence of massive ironstones. The most prominent of these occurrences are at Stations 33/31 and 45/7.

Copper mineralization

The andesitic metavolcanics are characterized by several occurrences of copper mineralization which often show very high assay values. At five stations (1/2, H5/3, 33/4, 33/10, and 21/10), boulders of mineralized andesite and ironstone were found in wadis. All assayed +1,000 ppm Cu and several also had high Ni (up to 1%) and Co (up to 1,350 ppm) contents. Wadi-sediment samples collected at these sites failed to show any anomalous values and the boulders are inferred to be derived from very small mineral occurrences.

At locality 10/A (MODS 2831, Bi'r al Mutaybah), malachite-staining accompanies extensive silicification along the contacts of a micro-granodiorite dyke. The dyke outcrops over 450 m and is up to 1.5 m wide. Systematic channel sampling showed copper values to range between 200 and 2,800 ppm over an average channel width of 1 m.

Discontinuous small bodies of ironstone and magnetite occur along a north-south trending shear zone at Station H4/9 (MODS 3009, Bi'r al Mutaybah H4/9). The shear was traced over 400 m and is up to 2 m wide. Systematic channel sampling shows values to range between 100 and 5,200 ppm over an average channel width of 1 m.

At Station 17/27, a 1-m wide crosscutting ironstone is exposed over a length of 20 m. Grab samples show anomalous Cu (max. 1,260 ppm) and Ni (max. 1,250 ppm) values.

6.3.3 SEDIMENTARY ENVIRONMENT

Small stratiform ironstones occur within dark pyrite-rich metasedimentary schists at a number of localities in the east of the Wadi al Lith - Wadi Salibah belt. All are too small to be of any significance.

At Stations 13/1 and 14/20, small stratiform ironstones contain low base- and precious-metal values, though Zn (15-270 ppm) and Ni (15-160 ppm) values are significantly higher than for ironstones in siliceous schists. Similar ironstones at Station 18/8 again show elevated Zn (200-1,100 ppm) and Ni (35-240 ppm) values. A series of small (0.5 x 50 m) ironstones, which occur along a single stratigraphic horizon within metamorphosed mafic medasedimentary tuffs and agglomerates at Station H9/7 and 20/10, have elevated Cu

(16-610 ppm) and Ni (15-170 ppm) contents. A small ironstone at Station 20/4 carries anomalous Cu (440-900 ppm) and Zn (360-475 ppm) values.

A series of small cupriferous ironstones outcrops intermittently along three linear zones immediately south of Jabal Qalqal at Station H7/15 (MODS 3004 Jabal Qalqal). The ironstones occur in a sequence of alternating sedimentary schists and andesitic flows which have been intruded by granite. The granite is strongly metasomatized. Isolated lenses of ironstone (1 x 25 m) outcrop in two zones over a strike length of 200 m and in a third zone over 100 m. The ironstones appear to have been emplaced along fault and/or shear zones. Systematic channel sampling returned consistent, high copper values ranging from 1,200 to 4,000 ppm over channel widths of 0.5 to 1.0 m. The occurrence is too small to be of any economic significance.

During 1402-1403 a few grab samples were collected from a large (10 x 200 m) lens of fine-grained, rusty quartzite in the northeast of the Jabal 'Afaf area (Station H14/8). One sample (out of 6) assayed 0.6 g/t Au. A large number of similar quartzites are present throughout the Jabal 'Afaf area and were systematically sampled during 1403. None showed gold values above the analytical threshold of 0.1 ppm, but several of the quartzites contained elevated Cu values (up to 470 ppm).

6.3.4 DIORITE COMPLEX

Several small outcrops of ironstone occur within rocks of the diorite complex at Station 4/1 (MODS 3005, Wadi Filh). The ironstones are developed within and adjacent to iron-stained rhyolite dykes and have maximum dimensions of 8 x 10 m. A few cupriferous quartz veins (up to 70 x 1 m) are also present. Systematic channel and grab sampling showed the ironstones to contain up to 1,000 ppm Cu and 0.4 ppm Au (one selected grab sample assayed 5 ppm Au), while the quartz veins assayed up to 1.5% Cu. The occurrences are of too small a size to warrant further investigation or entry into MODS.

6.3.5 QUARTZ VEINS

Large quartz veins are rare but at several localities swarms of small stratabound chlorite-bearing quartz veins occur within units of siliceous or intermediate schist. The vast majority of veins are not mineralized. None returned any Sn or W values, and only a few samples contained elevated gold and/or base-metal values.

At Station 17/17 (MODS 3006, Wadi al Lith), thin malachite-stained, auriferous quartz veins occur within altered andesitic flow rocks. The veins probably are faulted segments of a single quartz vein which measured some 1,500 x 1 m. Small lenses of ironstone are locally developed within the quartz vein and carry gold values up to 3 ppm. Systematic sampling showed the average gold content of the vein to be well below 1 ppm.

A single boulder of mineralized quartz-vein found in a wadi at Station 11/22 assayed 54 ppm Au. Helicopter reconnaissance failed to locate any sizeable quartz veins upstream and the boulder is inferred to be derived from a very small occurrence. Small stratabound quartz veins frequently occur within some of the layers of siliceous schist. At Station 21/20, these carry Pb and Zn values, and at 15/5, Cu values.

Small pods of massive ironstone occur adjacent to quartz veins at Stations 33/30 (MODS 3007, Wadi al Faqli) and H9/20. The former carries high Cu (2,000 ppm) values, while the latter is anomalous in Zn (1,000-5,000 ppm). Both are of insignificant size.

6.3.6 TERTIARY ROCKS

Several outcrops (Stations H4/2,3,4) of secondary transported ironstone (5-65% Fe) are developed over siliceous schist immediately below a prominent hill of Tertiary conglomeratic sediments. Examination of the Tertiary rocks themselves did not reveal any units of significant iron content, though several red-weathering hematitic shales are present. Systematic sampling showed these to contain less than 6% total iron.

6.4 MINERAL POTENTIAL

The present reconnaissance investigation systematically examined all geological environments present in the area which, on the basis of present knowledge, can be inferred to have potential for hosting mineral deposits. It was successfull in locating a large number of mineralized outcrops in an area in which no ancient workings are known. However, all these occurrences are small and none have any obvious mineral potential. In the light of these results, it seems extremely unlikely that a more detailed examination of the area will lead to the discovery of economically important mineralization.

Volcanogenic massive sulphide mineralization

The siliceous volcaniclastic schists appear to represent geological environments favourable to the development of volcanogenic massive sulphide mineralization. This is reinforced by the high-pyrite content of these rocks, the frequent presence of stratiform ironstones, the occasional presence of small base-metal-bearing ironstones, and the presence of rhyolitic volcanic centres.

The present investigation, however, shows the siliceous schists to characteristically occur as thin units interbedded with a variety of other volcanosedimentary rocks. This suggests unstable geological conditions with rapid changes in volcanosedimentary environments, allowing insufficient time for the formation of metal-bearing ironstones of any size. This is borne out by the frequent presence of small stratiform ironstones which typically are 10 to 20 cm thick and less than 100 m long.

Detailed mapping of some of the larger barren pyritic-ironstones also revealed these to be related to younger quartz veins and emplaced along faults and, despite their apparent stratiform nature, to be most likely epigenetic.

Andesite-related copper mineralization

The numerous occurrences of copper mineralization within the andesitic flow rocks in the south of the area are small and all appear to be epigenetic. Such scattered copper mineralization is typical of andesitic lavas world-wide and has no economic significance.

Porphyry copper mineralization

Geological and geochemical investigations found no evidence for the presence of porphyry copper mineralization in the porphyritic monzogranite pluton in area 12/14, as had been previously suggested (du Bray and Doebrich, 1981).

Gold mineralization

Rare gold values were found in ironstones, rhyolitic cherts, quartz veins and ferruginous quartzites. Systematic resampling showed the values to be extremely erratic and average gold tenors to be very low. While the above occurrences demonstrate the variety of geological conditions under which low-grade gold mineralization is present, the possibility of finding significant occurrences seems remote.

Sn, W and related mineralization

Heavy-mineral surveys indicate the presence of scheelite anomalies in the vicinity of Jabal Qalqal. Wolframite-pegmatite dykes were also found to occur in this area. Both types of mineralization appear to have no economic potential. The significance of heavy-mineral concentrate anomalies for Nb, Ce, Y, Ta and Th from this area remains to be assessed.

7 CONCLUSIONS

1 The geology of the area is complex and, as yet, poorly understood. This is particularly the case as far as stratigraphic subdivision and structure are concerned.

2 Photogeological interpretation delineated a number of geological environments with possible metallic mineral potential. These include:

a) Siliceous volcaniclastic rocks	- Volcanogenic base- and precious-metal mineralization
b) Andesitic flow rocks	- Epigenetic copper mineralization
c) Sedimentary rocks	- Distal volcanogenic base- and precious-metal mineralization
d) Dioritic complex	- Epigranitic base- and precious-metal veins
e) Young granite plutons	- Tin, tungsten, REE and related mineralization
f) Tertiary rocks	- Sedimentary ironstones.

3 Systematic reconnaissance of the various geological environments revealed numerous small mineralized outcrops, as well as rock units showing various forms of geochemical enrichment.

4 All the occurrences are too small to warrant further investigation, and the area appears unlikely to contain any significant base- or precious-metal mineralization.

5 No ancient workings were located in the area examined.

8 RECOMMENDATIONS

1 Further geological mapping of the area is recommended in order to solve problems of regional structure and of stratigraphic correlation.

2 Limited low-priority follow-up is recommended over the following areas:

a) The geochemical anomaly of area 20/10,
b) The pyritic quartzite horizon at stations, and
c) The Nb, Ce, Y, Ta and Tb anomalies at Jabal Qalqal.

3 Apart from the above low-priority investigations, no further mineral exploration is recommended.

9 DATA STORAGE

9.1 DATA FILE

All original data relating to the work described in this report are stored in Riofinex Data-File RF-BD-01-04.

9.2 MINERAL OCCURRENCE DOCUMENTATION SYSTEM (MODS)

The following occurrences have been submitted for entry in MODS records:

MODS No.	Occurrence	Field Station	Riofinex Submission No.
2831	Bi'r al Mutaybah 10/A	10/A	RFX 102
3003	Wadi Tisba'	27/16	RFX 98
3004	Jabal Qalqal	47/15	RFX 104
3005	Wadi Filh	4/1	RFX 103
3006	Wadi al Lith	17/17	RFX 101
3007	Wadi al Faqli	33/30	RFX 100
3008	Wadi Iyar	24/3	RFX 99
3009	Bi'r al Mutaybah H4/9	H4/9	RFX 105

The existing MODS file for Gumayqah Northwest (2088) has been updated.

The number of this report was inserted in the bibliography of all the above MODS records.

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