Qatar Univ. Sci J. (1999), 19:

DISCRIMINATION OF COASTAL SEDIMENTS AROUND QATAR PENINSULA, USING REMOTE SENSING TECHNIQUES

By

A. Ali M. Sadiq and Ibrahim A. El-Kassas
Department, of Geology, Faculty of Science University of Qatar, Doha, Qatar

التميز بن الرواسب الساحلية حول شبه جزيرة قطر بإستخدام تقنيات الإستشعار عن بعد

عبد العلي محمد صادق وإبراهيم علي القصاص

إستهدفت هذه الدراسة توضيح الإستفادة من تقنيات الإستشعار عن بعد في التعرف على الأنواع المختلفة للرواسب الساحلية حول شبه جزيرة قطر. وفي هذا المجال فإن البيانات الرقمية المسجلة في عدة مجالات طيفية من الماسح النوعي للقمر الصناعي لاندسات تمثل وسيلة فعالة لتحديد الفروق الطيفية المفيدة في التميز بين أنواع الرواسب الساحلية والتي تعتمد على خصائصها الفيزيائية ومكوناتها المعدنية وتركيبها الكيميائي.

في البداية تم إجراء معالجة أولية للبيانات الأصلية المسجلة مباشرة من الماسح النوعي بالقمر الصناعي « لاندسات » وذلك لعمل التصحيحات الإشعاعية والهندسية ، ثم إستخدمت عدة طرق للمعالجة الرقمية لهذه البيانات المصححة شملت طرقا مختلفة لتحسين الصور الناتجة عن البيانات وتصنيفها وكذلك عدة محاولات لخلط بيانات المجالات الطيفية المختلفة . كما تضمنت الدراسة تجميع معلومات أرضية من بعض المواقع المختارة على إمتداد الساحل القطري ، وتم فيها أيضا قياس الإنعكاسات الطيفية للرواسب الساحلية باستخدام أجهزة حقلية ، حيث استخدمت بعض البيانات إحصائياً لمجموعات تدريبية في عمليات التصنيف وإعداد الخرائط خلال المعالجة الرقمية.

وقد أوضحت نتائج هذه الدراسة أن إستخدام خليط من بيانات ثلاث موجات طيفية متضمنة مجال ضوء مرئي (المجال ١ , ٢) ومجالي الاشعة تحت الحمراء القريبة والمتوسطة يعطي افضل تمييز بين الرواسب الساحلية. كما أثبتت التقنيات المستخدمة أنه يمكن الإستفادة منها بدرجة كبيرة خاصة في المناطق التي تظهر فيها مكاشف أرضية ذات تضاريس بسيطة.

Key words : *Digital Image Processing, Landsat-TM,Sediments, Qatar Peninsula*

ABSTRACT

This paper aims at demonstrating the usedfulness of remote sensing techniques in identifying various types of coastal sediments around Qatar Peninusla. In this respect, Landsat-Thematic mapper (TM) multispectral data provide a valuable tool to detemine spectaral differences, applicalbe to discriminate coastal sediments, based on their physical characteristics, mineralogical constituents and chemical composition.

Preprocessing of the Landsat-TM row dara was first perfourmed for rdiometric and geometric corrections. This was followed by various image processing techniques including differnt enchancement methods, categorizations and various combinations of spectral bands. Ground-truth information was collected from some selected areas along the coastal zone, where reflectance was measuerd in the field. Some of these data were statistically used as training sets for categorization and map prepartion thuough digital image processing.

The study revealed that the use of a three-band combination of Landsat-TM data, including a visible band; near and middle infrared (IR), provides the best discrimintaion of coastal sediments. The applied technique can be most valuable particularly in areas where the sediments show good exposusers with some gentle topography.

INTRODUCTION

The coastal zone forms an important segment of Qatar Peninsula, which has a long coastline of some 700 km. The land/water interface comprising coastal zone is modified by the action of wind, sea currents, waves and tidal oscillations, where various sediments are transported, dispersed and depositd. An irregular distribution of various types of surficial sediments is a characteristic feature of the coastal zone of Qatar Peninsula. Aeolian sands occur in the form of mobile thin sheets, small hummock dunes, barchans and large dune fields. The prevailing northerly winds (Al-Shamal) causes the aeolian sands to be heavily concentrated along the southeasten coast where numerous barchen dunes progressively coallesse into an extensive dune field encroaching over coastal sabkhas. Most of the coastal sabkhas are saline flats or playa, composed of fine calcareous sands with variable amount of silts and clays. Recent calcareous beach sands are principally localized along the present coast line, but they also occur at the edge of or within the sabkas, outlining areas previously covered by the Quaternary sea. They are composed essentially of unconsolidated, whitish brown sand consisiting of small shells and worn shell fragments which accumulate above the ligh water mark by wave action.

In fact, most of the previous studies on the geology and geomorphology of Qatar Peninsula have included the coastal sediments in a general way. The most important of these studies include those of

Cavelier (1), FAO (2), Purser (3), Shinn (4,5), Vita-Finzi (6) SEL (7), Perthuisot (8), Batanouny (9), Embabi (10), Embabi and Ashour (11,12), Embabi (13), Ashour (14), Focke (15), Al-Sheeb (16), With the advent of remot sensing technology, aerial photographs adn satellite images have been used ot study some eolian features and in geomoephological mapping of Qatar Peninusla by Ashour and El-Kassas (17, 18), Recently, Akbar (19,20) and Khamis (21,22) applied some digital processing techniques on Landsat imagery data to investigate various surficial deposits of Qatar Pennsula.

In the present work, a wide range of image processing techniques are tested on the raw Landsat-TM data, ot obtain maximum discrimination of various sediments in the coastal zone of Qatar Peninsula. This work is corroborated with intensive fieldwork for collecting ground truth information including spectral reflectance and sampling various types of coastal sediments for further laboratory studies.

MATERIAL AND METHODOLOGY

The results displayed in this paper are based on the compilation of all available physiographic and geologic information, intergrated with remote sensing data from Lndsat-5 Thematic Mapper (TM), field work and laboratory analysis, The used materials and methodology include :

1) Topographic maps of Qatar, at scales 1:200,000; 1:100,000 and 1:50,000.
2) Geological map of Qatar, at scales 1:200,000; 1:100,000 (1,7)
3) Aerial photographs, normal black-and-white prints, scale 1:38,000.
4) Digital satellite data from Lndsat-5 TM as a mosaic for Qatar of February 1987, and a scene covernig nothern Qatar Peninsula of June 1990. Various image processing techniques have been carried out on these data using the ERDAS software (version 7.5), running on a Sun 4/260 workstation. This is a high-level iamge processing system which includes functins for input, display and analysis of raster sets (23). The acquired satelite raw digital data were preprocessed for radiometric and geometric corrections to produce rectified iamges. Then we conducted various image processing techniques, including image enhacncement (contrast stretching), categorization or classification (supervised and unsuperviesd), false-color compoites from various possible three-band combinations, image filtering and other techniques.
5) Ground spectral reflectance measurements, using the Single Field-of-view Infra-Red Geophysical and Environmental Research Corp., GER (24). Spectral reflectance was measured in the field covering several exposures of the different types of coastal sediments, from which representative sample were collected. The samd SIRIS equipment was also used inthe laboratory for spectral measurements of these samples. The measured spectra were reduced to be comparable with Landsat-TM reflectance values, using Batch Processign Programs (25).

6) Laboratory Analyses : In addition to spectral measurements, mechanical and mineralogical analyses have been carried out. on 53 random samples collected from the varous coastal sediments. From mechanical analysis the mean grain size and other statistical parameters (mode, median, skewness and kurtosis) have been calculated to describe the distribution pattern of each type of sediments (Table 1). For mineralogical analysis, the standard X-ray diffraction (XRD) technique was applied for semi-quantiative determination of the bulk mineralogy of the coastal samples (Table 2).

		Sabkha-derived	Beach-derived	Dune sand
Grain size	phi (ϕ) units	Mean w%	Mean w%	Mean w%
>2000μm	-1	4.36	7.15	5.24
>1000μm	0	6.81	12.72	4.83
>500μm	1	23.27	26.22	5.12
>250μm	2	19.24	28.12	15.2
>125μm	3	22.60	18.97	29.74
>63μm	4	21.26	4.43	37.29
<63μm	>4	2.32	1.44	2.38
Mode		500-1000μm	250-500μm	63-125μm

Table (1): The statistical results of the grain size analysis of 53 sand samples collected.

	Sabkha-derived sand	Beach-derived sand	Dune sand
Quartz	***	*	***
Aragonite	x	***	*
Calcite	*	**	*
Mgcalcite	*	*	*
Dolomite	*	*	*
Gypsum	**	x	x
Halite	*	x	x
Plagioclase Feldspar	*	x	*
K-Feldspar	*	x	*

Table (2): Main minerals as indicated by XRD analysis, symbols as follows: Abundant- ***, Moderate- **,Trace- * and None- x.

GEOMORPHOLOGICAL FEATURES OF COASTAL SEDIMENTS

The surface of the coastal zone of Qatar Peninsula is generally of low relief forming alomst flat sandy plain with some undulations and occasional outcrops of consolidated Quaternary beach rocks that form small to moderate hillocks. Also, along the coastline sabkhas to the alomst dry sand and very fine grain size with different shape of accumulation. Spectral bands that approximate those of Lndasat-TM and which are diagnostic of the surficial sediments were selected for various analyses. The various sand types show similar reflectances in the visible bands while the main distinguishing features are derived from the IR bands (5 and 7).

The results revealed that three sand types can be spectrally identified : (1) sabkha-derived salt-rich quartz sand; (2) beach-derived calcareous sand and (3) aeolian dune quartz sand. The latter is mainly continental deposits and contains a higher percentage of sand has more gypsum and more grains of salutation size (125-250 µm) and also more symmetrical distribution than others. It generally lacks coarser grains such as occur in the calcareous sand (with grains > 250 µm) and lacks fine grains such as those occur in dune sand (a high proportion<63 µm) Grain size and relative homogeneity of composition based on x-ray diffraction and direct visual observation were taken into account during the measurement of reflectance. These results provided some information about the various sand types (Table 3).

Table (3), Summary of Results of Grain Size and X-Ray Analyses of Various Sand Types in Coastal Zone of Qatar Peninusla

Sand Type / Analysis	Sabkha-derived sand	Beach-derived sand	Aeolian-dune sand
Dominant mineralogy	Quartz, Gypsum	Aragonite, Calcite	Quartz
Grain size mode	500-100 µm	250-500 µm	63-125 µm
Sorting	poor	moderate	Well-sorted

Most of the surficial sand deposits in the coastal zone of Qatar Peninsula are dominantly composed of quartz particles. The beach-derived sands have more carbonate though. The sand grains are sorted by wind, on the basis of grian size, into several different sand types.

This can be distinguished on the ground by their characteristic (saline flats) are a common feature covering extensive areas of salty sand deposits nearly at or just above sea level. On the other hand, aeolean sand are accumulated in the southeastern coastal zone to form a significant field of sand dunes and ridges named Al-Nijyan (11-12).

Geologically, marine deposits of Quaternary age are found around the Qatari coasts and consist manily of cemented calcarenites or pseudo-oolitic limestone wiht some basal conglomeratic limestone (1,7). These deposits form some prominent ridges at Jable Fuwairet, Jassassiyah and Al-Wakra, along the northern and eastern coasts, where their elongation represents the earlier (Pleistocene?) coast line (8). Other beach rocks of weakly consolidated limestone are found in some coastal areas forming minor terraces of generally 2-3m thickness.

Alomst all around the whole coast of Qatar Peninsula there are recent beach deposits formed of unconsolidated calcareous and quartizitic sands, ranging in age from 4690± 80 to>35000 years before present (6). The most important continental deposits of Quatenary to recent age are the geolean deposits that form a large dune field along the southeastern coastal zone of Qatar Peninsula, in the area south of Messaieed (11,12).

RESULTS AND DISCUSSION

The image processing techniques perform and unlimited number of mathematical functions to convert Digital Number (DN) values of Landsat-TM to spectral reflectance. These operations have been verified by field and laboratory spectrometric measurements. Integrating these data sets showed a good correspondence or correlations of the wavelengths maximum sensitivity between the three spectral measurements. The ground and laboratory spectral radiances are generally higher than those of Landsat-TM. This is due to several factors such as atmospheric conditions, low relief, resolution and scale. However, for areas wiht larger sand dunes, Landsat-TM spectral reflectance is higher than field and laboratory reflectances. This is due morphology as well as by internal patterns are evident because of constant strong wind, absence of running water, and lack of vegetation.

On the regional extent, greater variety of these surficial sand deposits is more apparent on Landsat-TM images than on the ground, because surficial materials exhibit more distinguishable features in the near IR wavelengths than in the visible wavelengths. As such, Landsat-TM-false-color images are valuable tool for mapping surficial deposits in arid regions.

Some of the spectral reflectances seen on TM images appear to be conicident with certain morphological units such as the large dune fields, but others, particularly streacks of various hues, appear to represent windblown materials that have been added to the primary geolean deposits and have been added to the original deposits and have modified thier surface mineralogy. Some of these mantling surficial deposits can be traced by thier spectral characteristics to specific source materials redistributed by the prevailing wind over known distances.

The spectral reflectance and emittance characteristics of sand types in different wavelength regions are result of different physical and chemical properties. The spectral reflectrances of various sand types in the visibal wavelength range are alomst similar. However, In the IR range the spectal reflectance creates a different features curve due to the effects of grain size and mineralogical composition. Thus as indicated by (25), the combined use of reflectance data obtained from imagery, field and laboratoy methods proves to be usefull tool for mapping surficial sand types in arid regions.

CONCLUSION

This study showed the potential use of satellite remote sensing techniques to discriminate between various types of coastal sediments around Qatar Peninusla, based on thier spectral reflectances.

Varitations in the mineralogy, grain size textrue, moisture content and other physical and chemical properties of different sand types in alomst-flat desert terrain of Qatar Peninsula, can be expressed in their spectral characteristics. It has been found that the use of a three-band combination of Landsat-TM data, including a visible band, near and middle IR, provides the best discrimination of coastal sediments. The applied technique can be most valuable particularly in areas where the sediments show good exposures with some gentle topography. The main restrictions in using Landsat satellite data are : (a) adapating the scale of satellite data to the scale of the spectral changers and (b) the intercalating and mixing nature of coastal sediments. However, for regional studies, such an analysis is useful in planning the development of coastal zone with respect to fisheries, salines, contaminated or oil-polluted areas and in monitoring environmental changes due to coastal processes.

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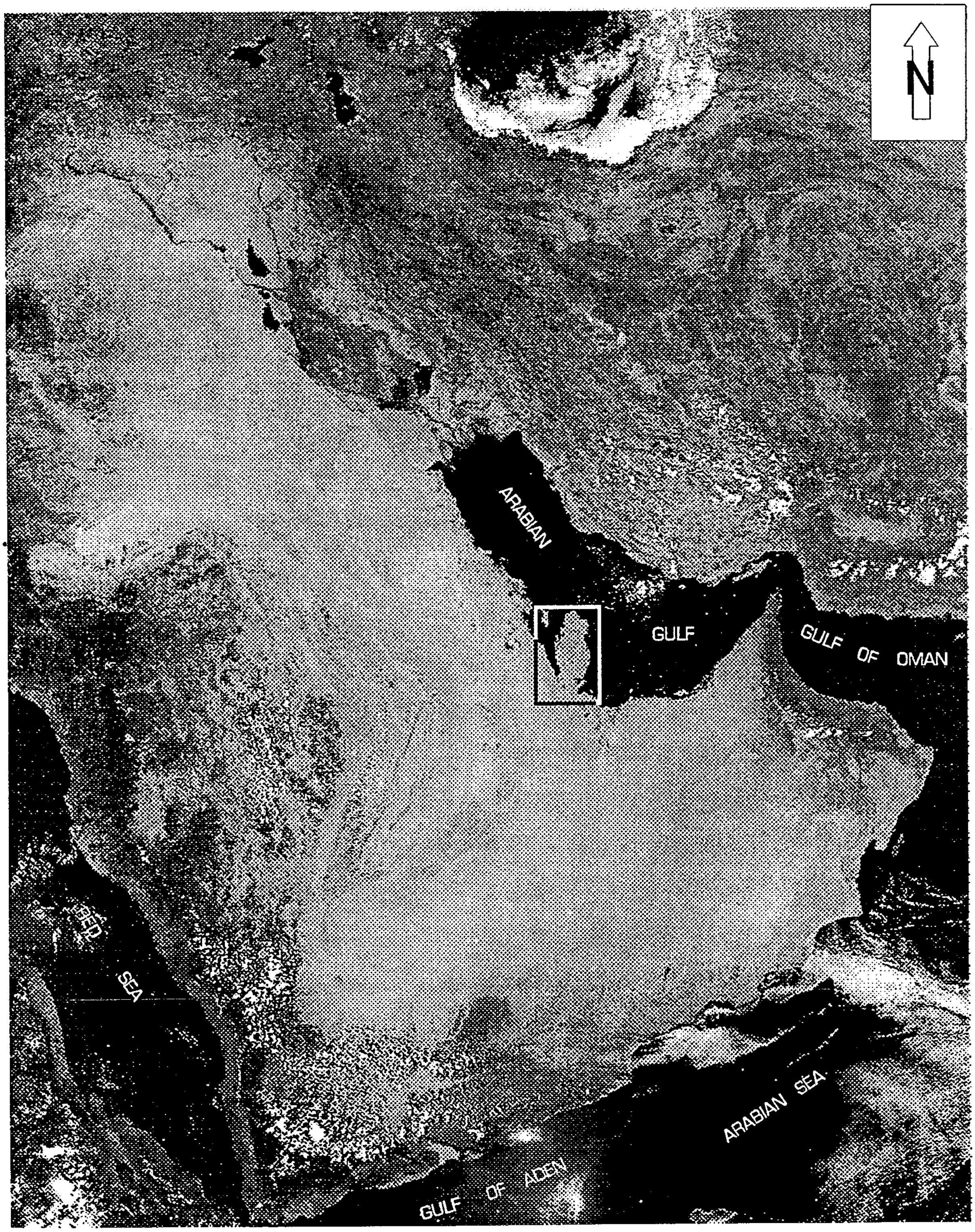
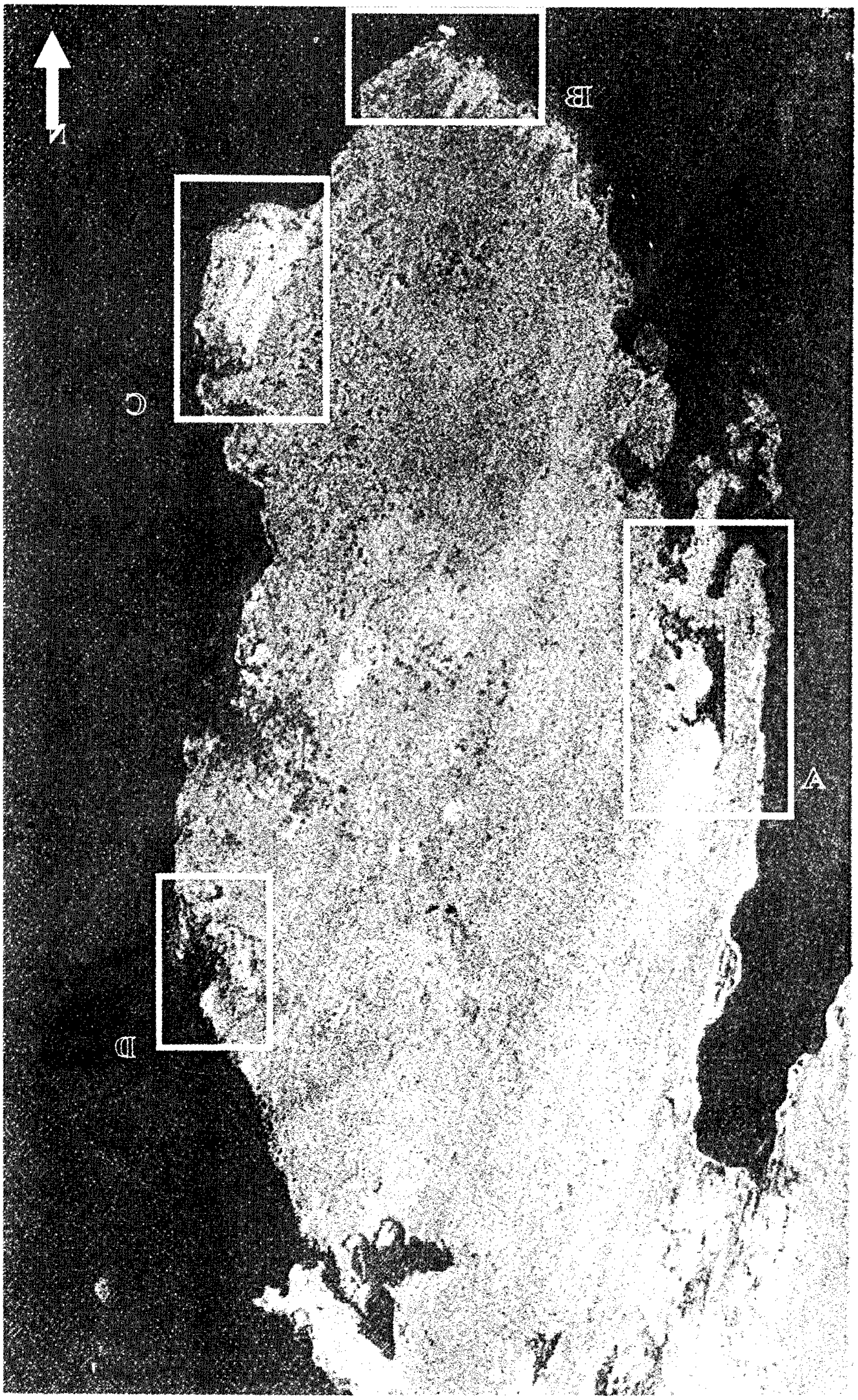


Figure (1): The Location of Qatar and the Deserts of Arabia.

(NOAA - AVHRR)

0 200 km

(Fig. 1)



Approx. Scale 0 40 km

Figure(2): Landsat TM-5 Natural Color Composite Image of Qatar Peninsula.

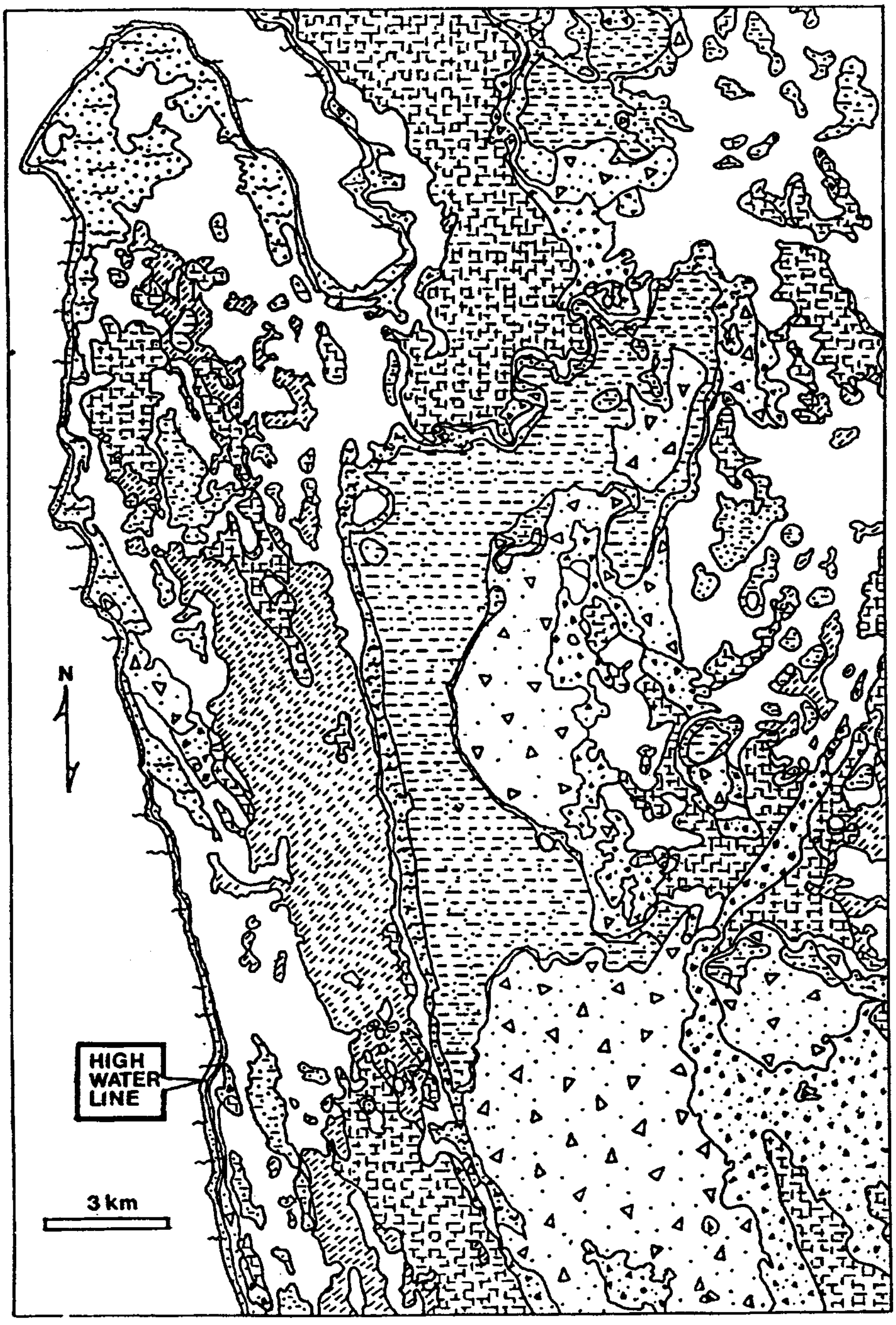


Figure (3): Surficial map of west Qatar (Area 1), compiled from the interpretation of Landsat FCC, 751 (RGB), PC, 123 (RGB) and classification result.

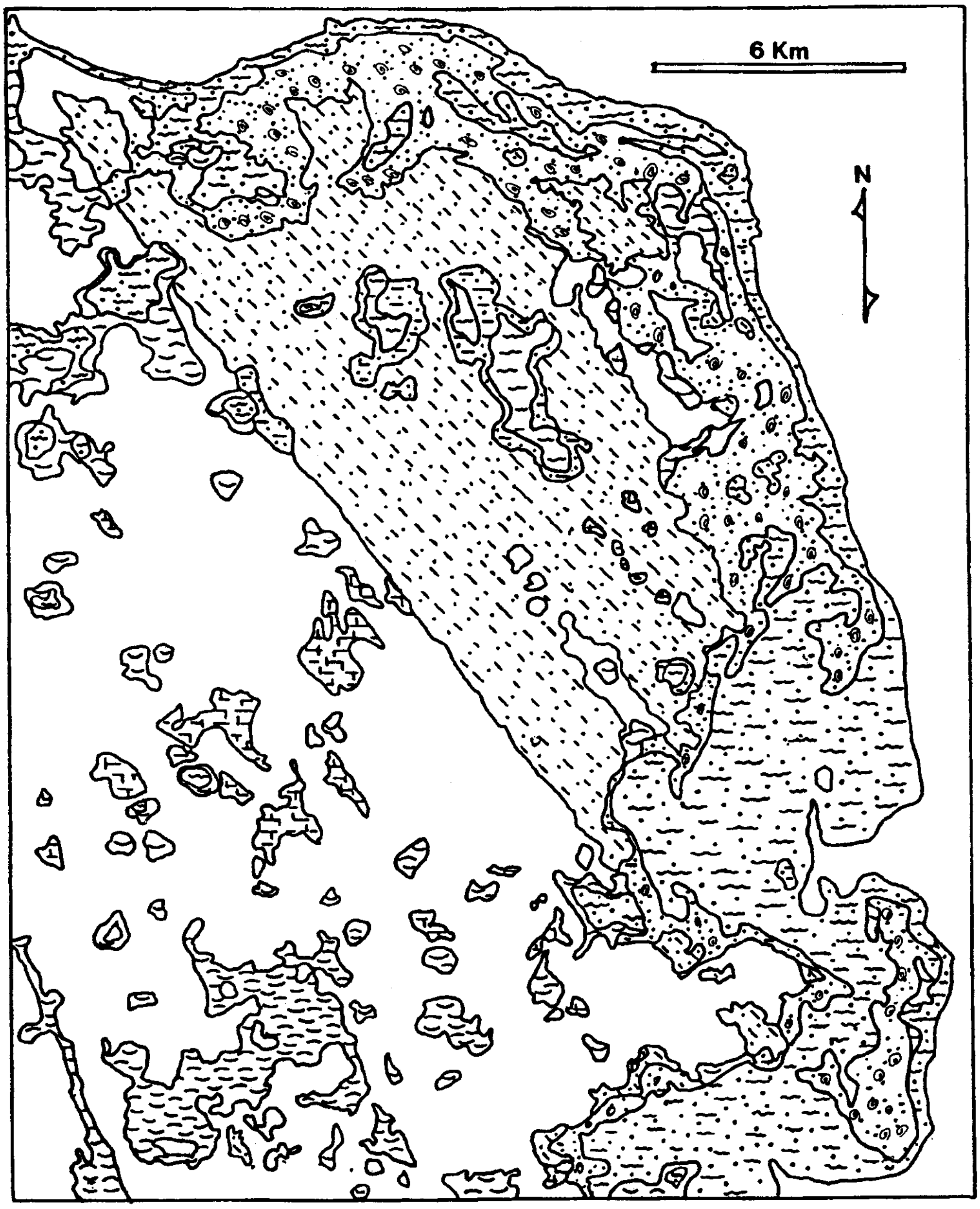


Figure (4): Surficial map of northeast coast Qatar (Area 2), compiled from the interpretation of Landsat FCC, 753 (RGB), PC,123 (RGB) and classification result.

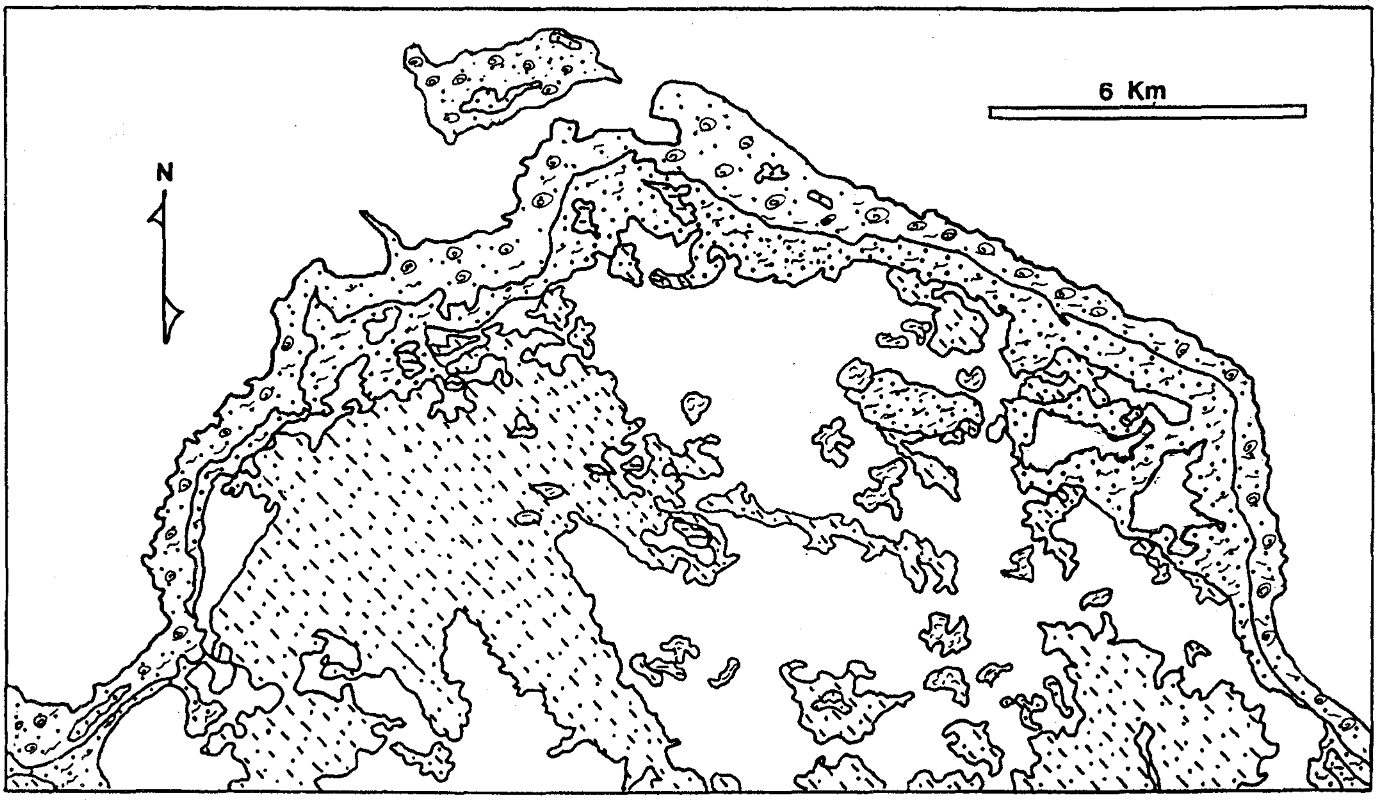


Figure (5): Surficial map of north tip Qatar (Area 3), compiled from the interpretation of Landsat FCC, 753 (RGB), PC, 123 (RGB) and classification result.

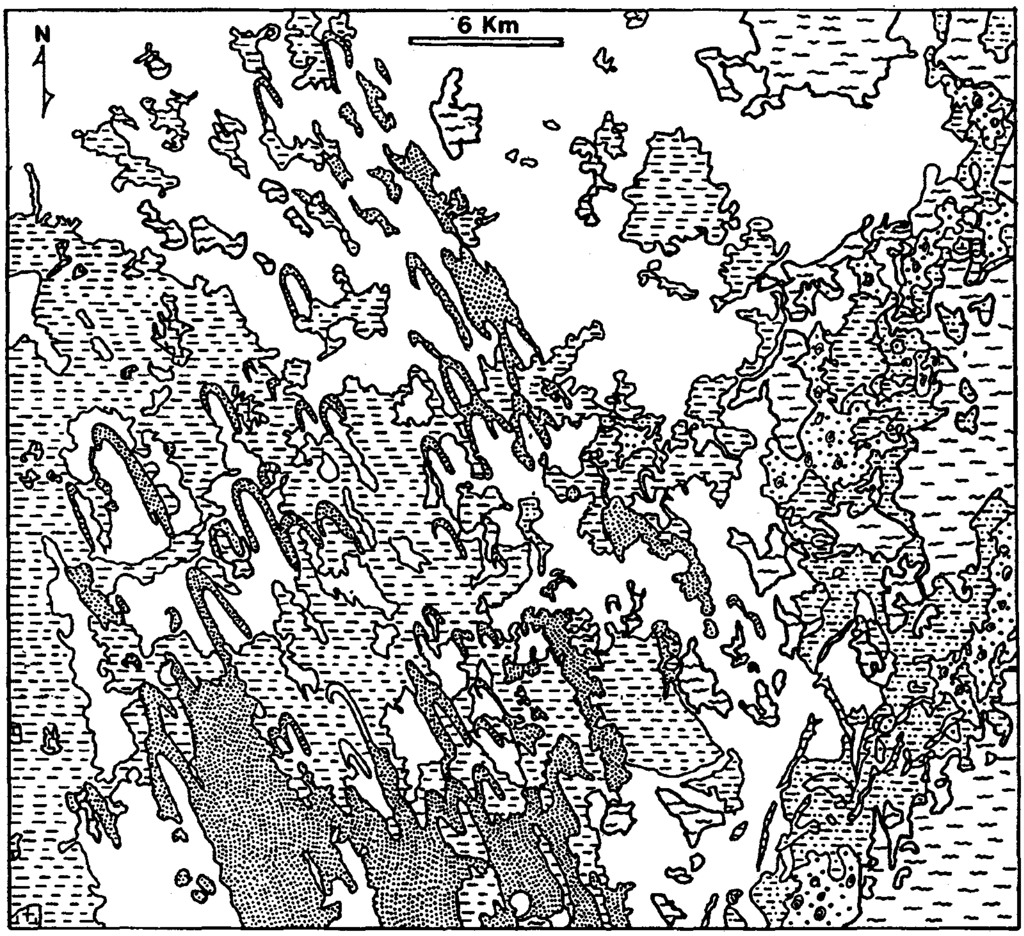


Figure (6): Surficial map of southeast coast Qatar (Area 4), Compiled

Quaternary

Coastal sabkha. Saline and gypsiferous sand and silts flats, partly covered with water.

Inland sabkha. Saline and gypsiferous sand and silt flats, usually dry.

Sabkha-derived salt-rich quartz sand, with gypsum.

Beach-derived calcareous sand.

Blown calcareous sand sheet.

Dune sand, mostly quartz.

Depression, fine grained silt and sand, commonly calcareous.

Reg of chert pebbles with quartz sand.

Tertiary

Upper Dammam Formation. Dolomite and limestone. (Simsima Member)

Lower Dammam Formation. Shale, limestone and dolomite, including Midra Shale.

Rus Formation Limestone and dolomite.

(Fig. 7)

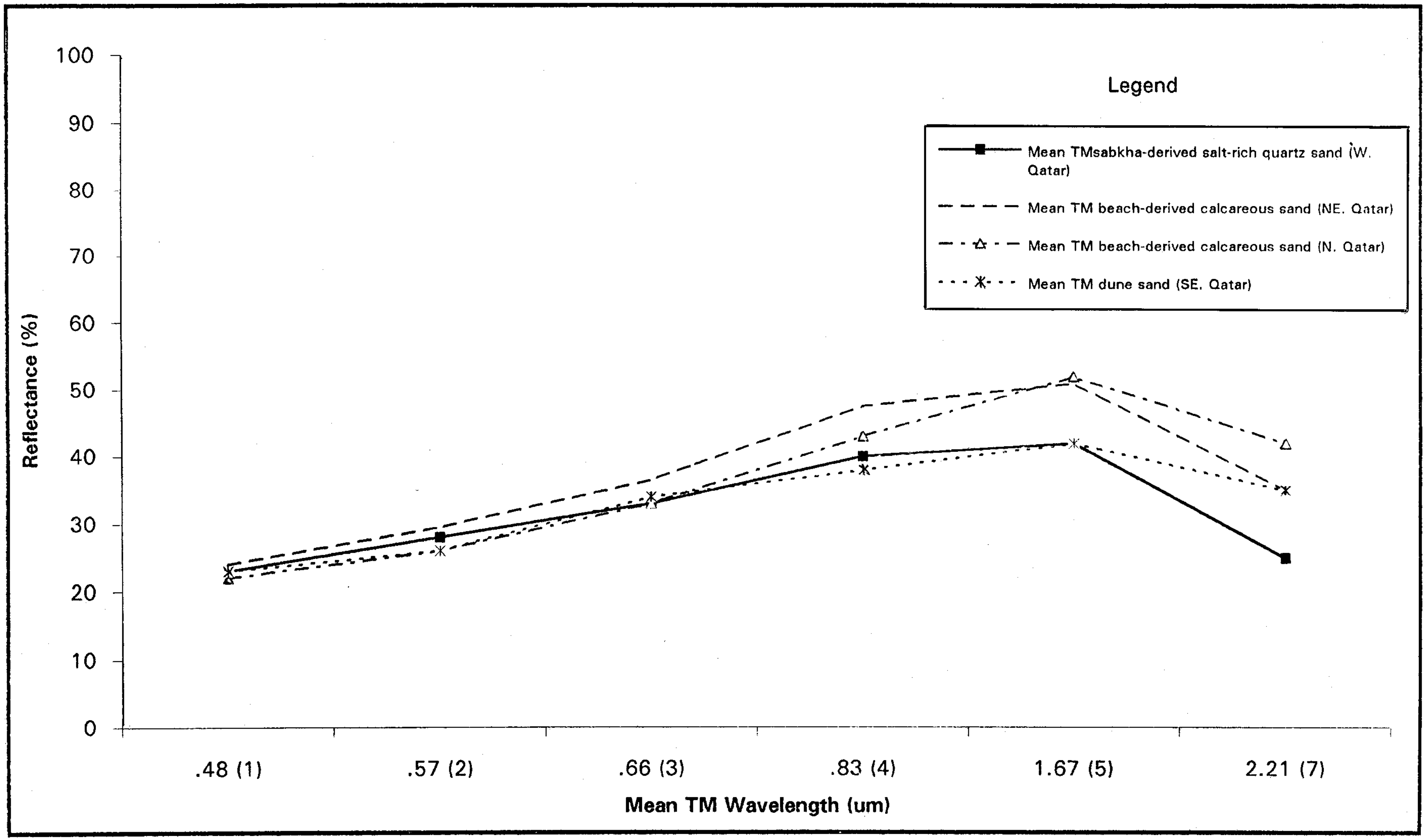


Figure (8): Landsat TM mean spectral reflectance of various sand types Qatar Peninsula.

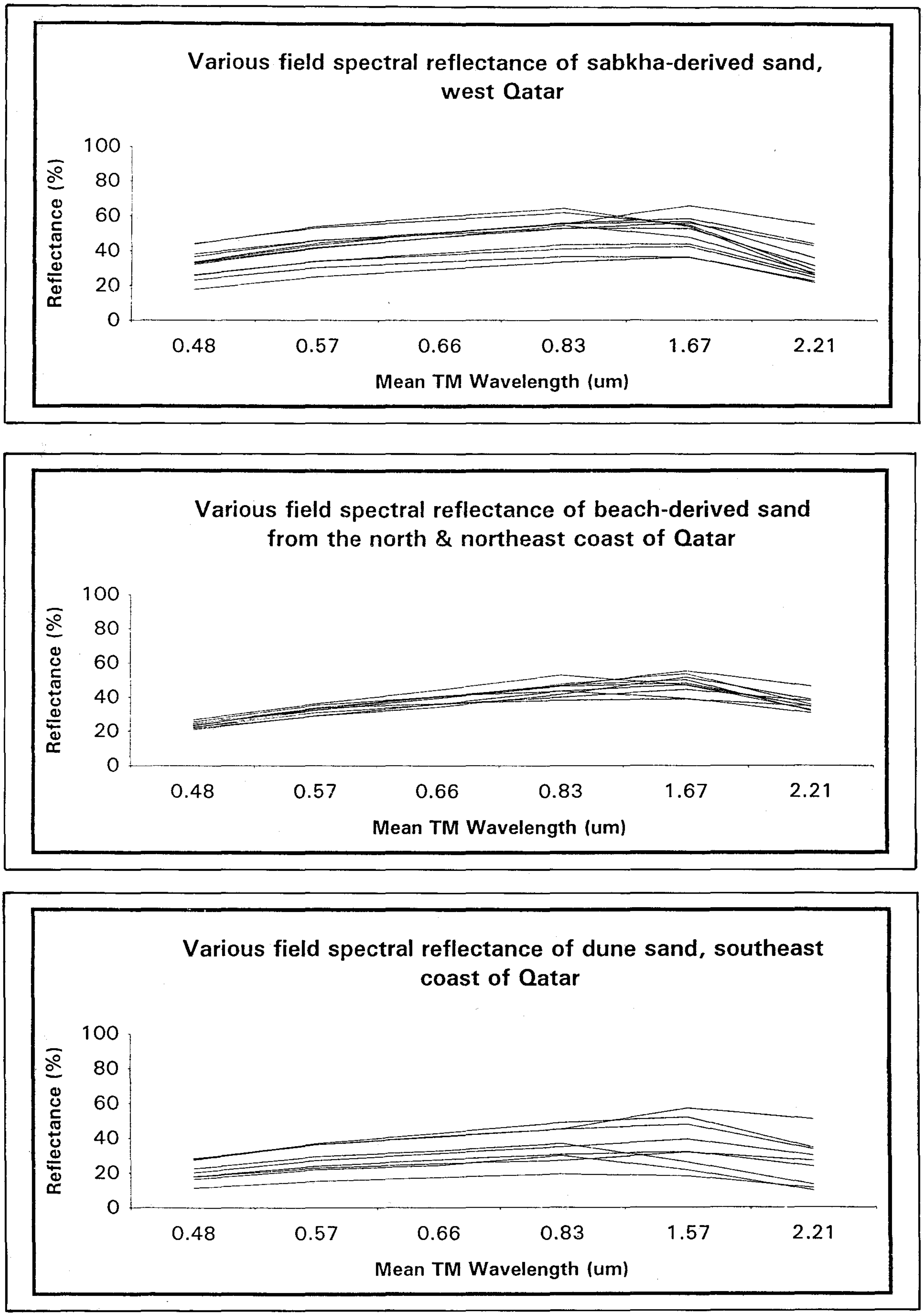
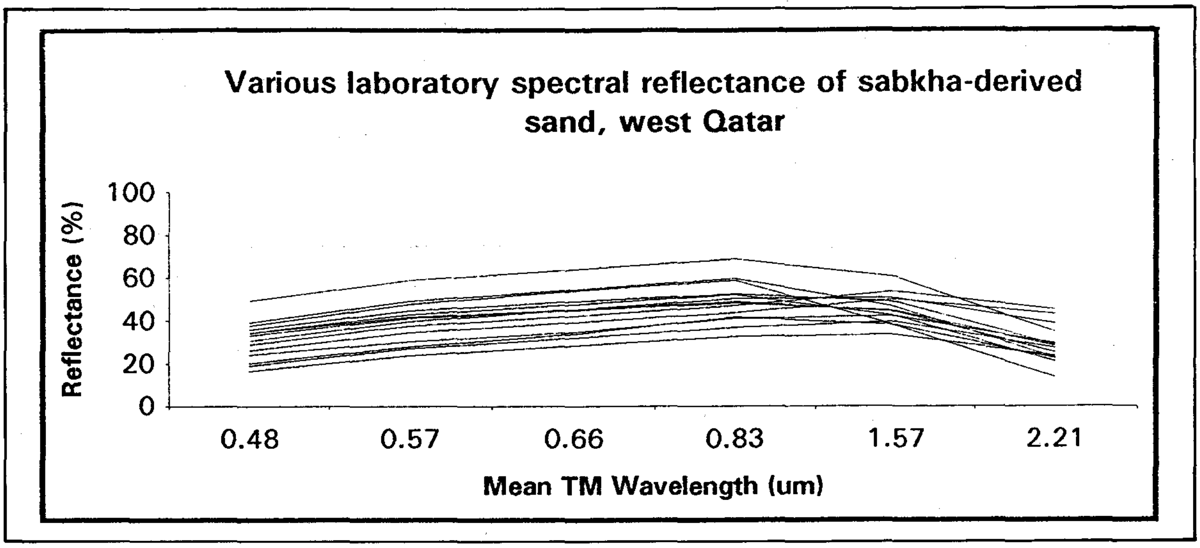
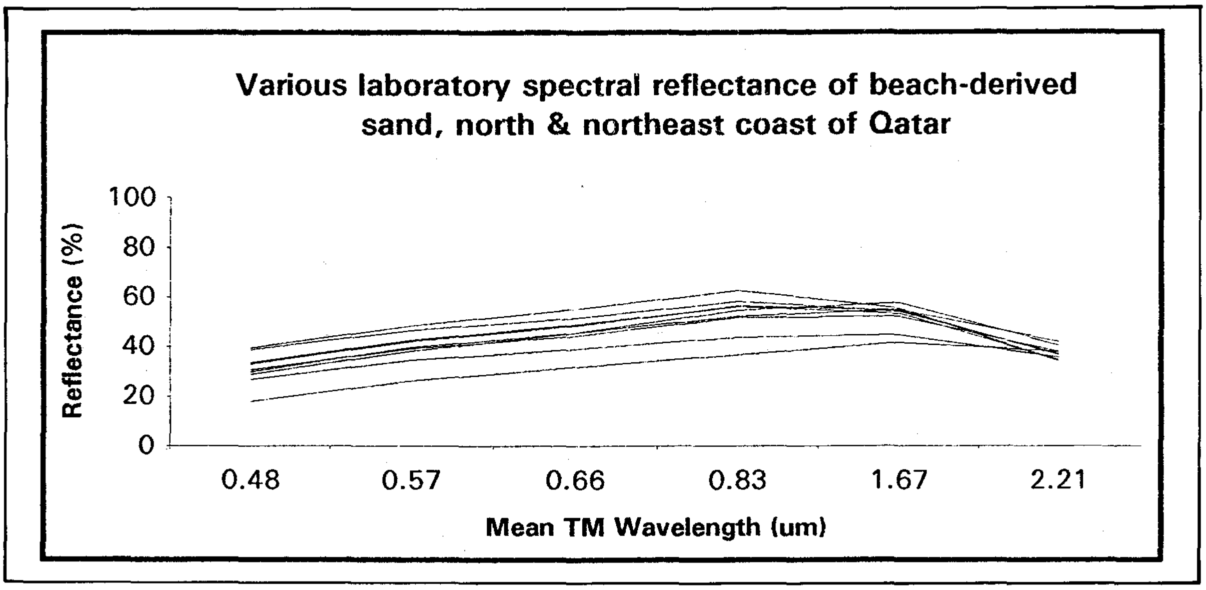


Figure (9): Variable example of field spectral reflectance from the three sand types.





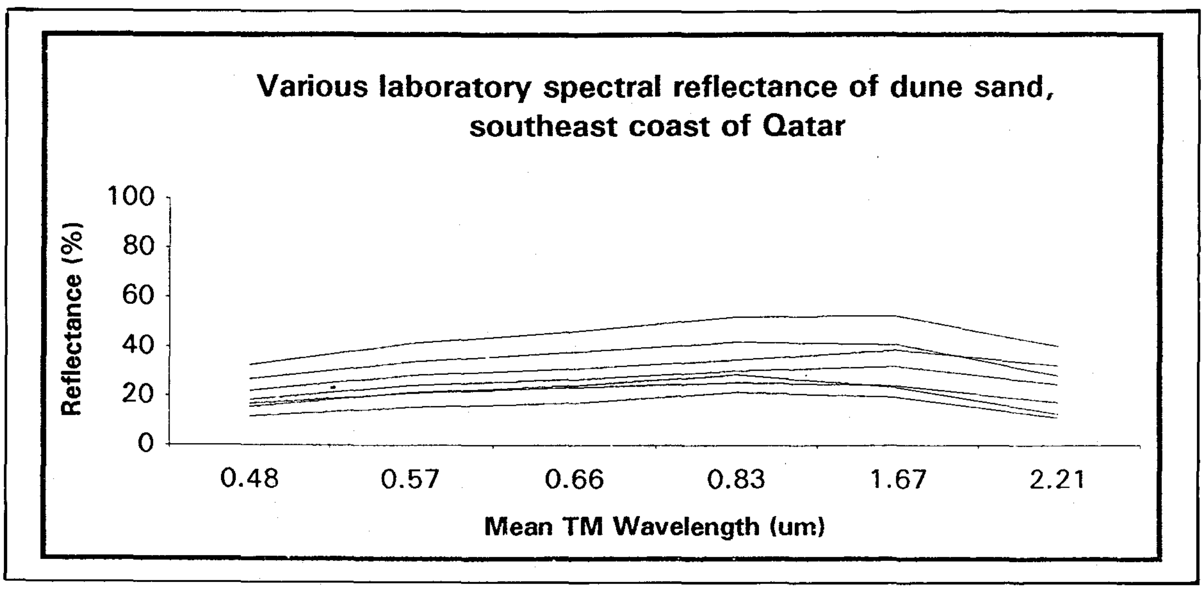


Figure (10): Various examples of laboratory spectral reflectance from the three sand types.

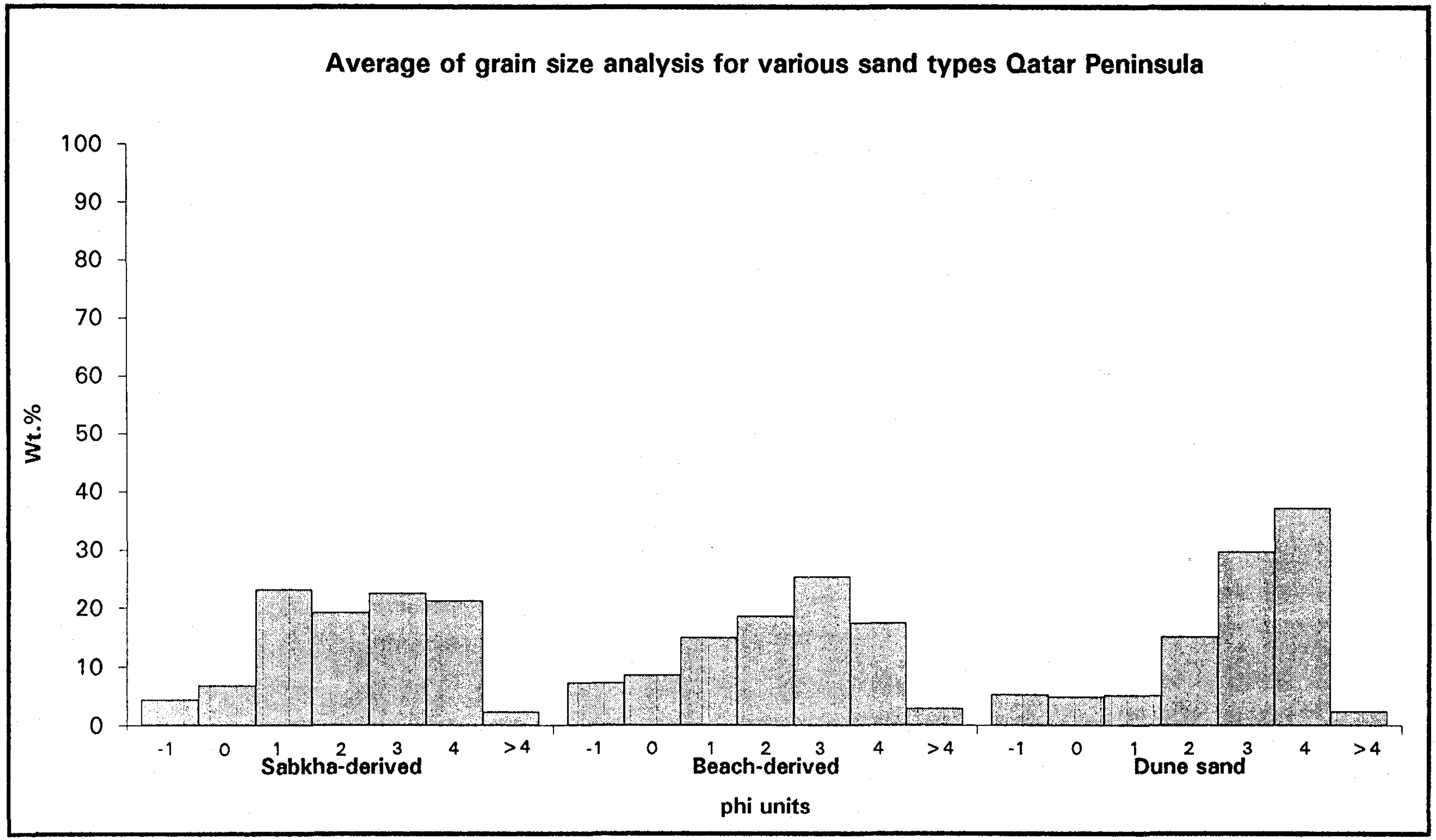


Figure (11): Average of grain size analysis for various sand types Qatar Peninsula, all areas studied.

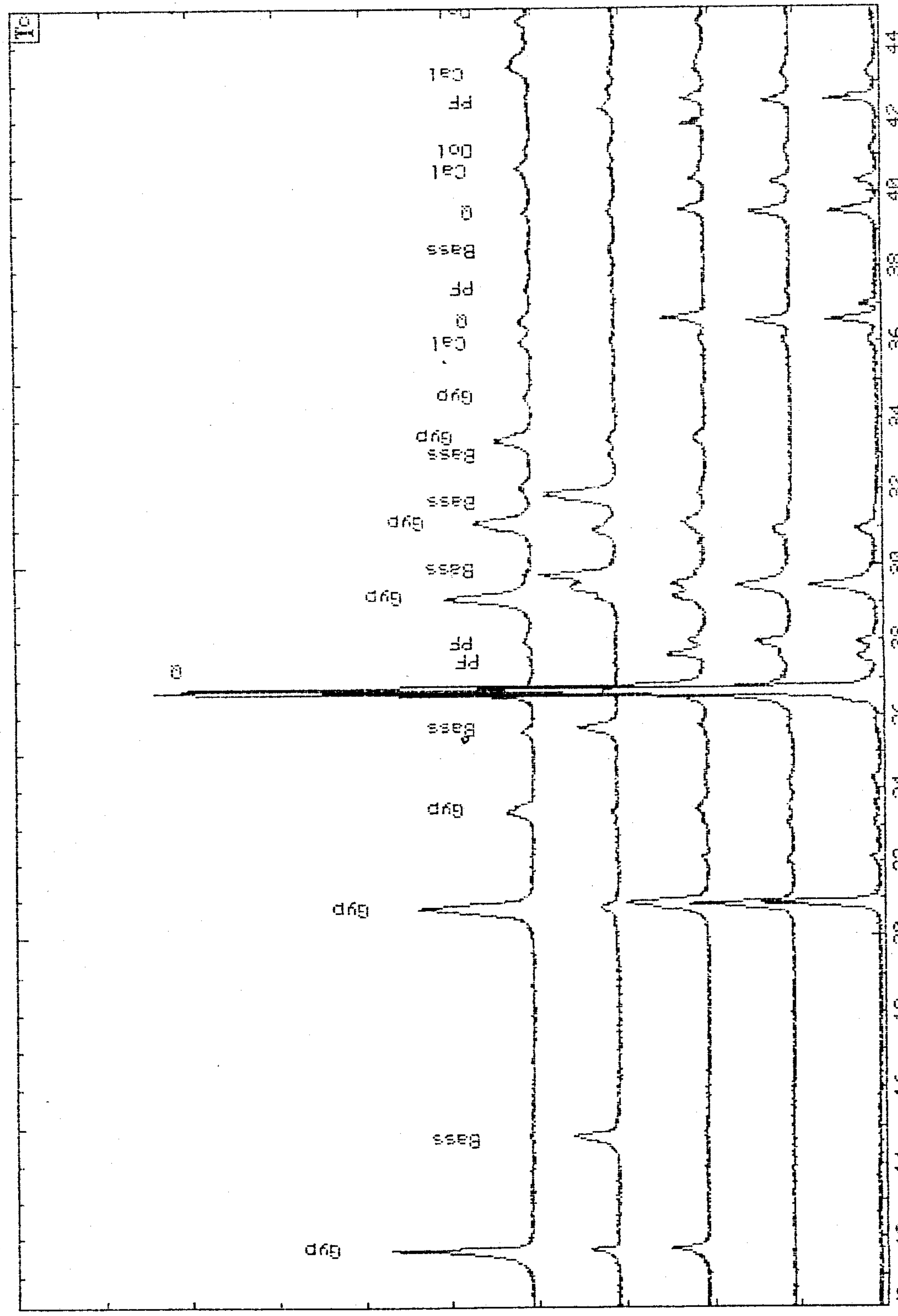
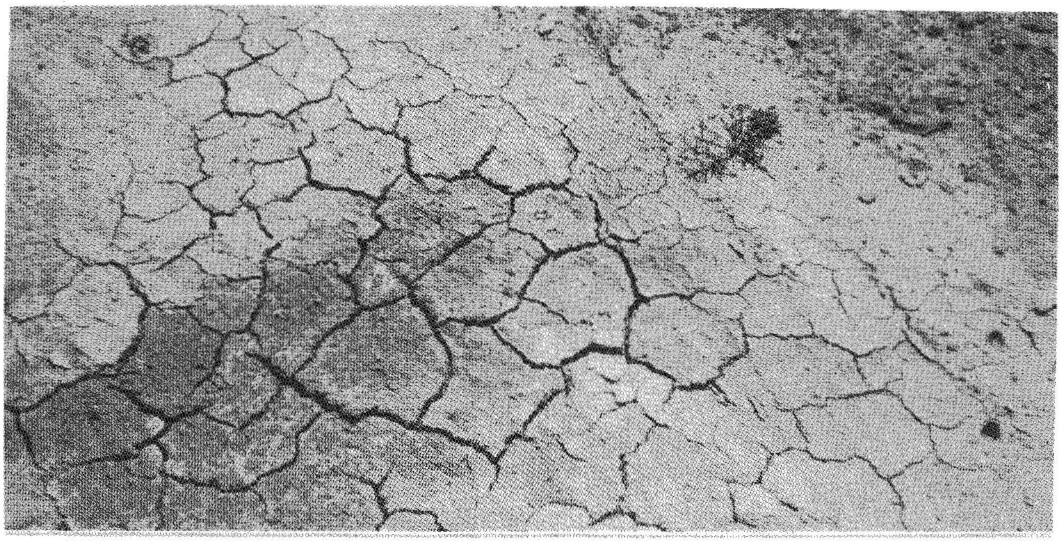
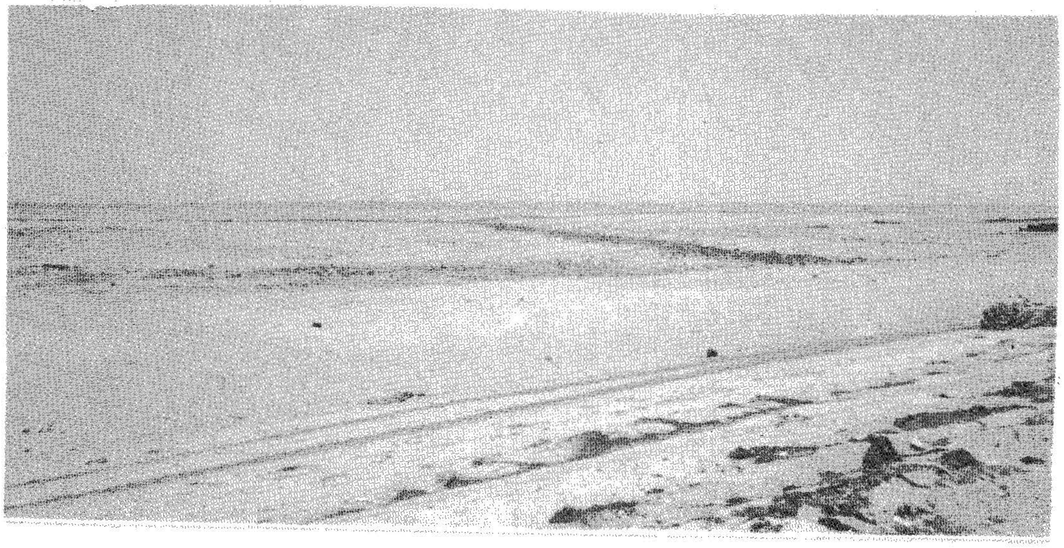


Figure (12): Examples of XRD analysis for sabkha-derived sand from west Qatar Peninsula.





(Fig. 13)