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Mineralogy and Chemistry of Desert Roses, Ayn Dar Area, Abqaiq, Eastern Province, Saudi Arabia

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معادن وكيمياء ورود الصحراء عين دار، أبقيق، المنطقة الشرقية، المملكة العربية السعودية

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ورود الصحراء هي بلورات تأخذ غالباً شكل بتلة الورد، وتملك ورود الصحراء أشكالاً بلورية محددة، وتحتوي على حبيبات رمل، وتوجد ورود الصحراء متبعثرة على مساحة تقرب من ٥٠٠م٢ في منطقة عين دار، قرب ابقيق، حوالي ٨٠كم جنوب غرب مدينة الدمام بالمنطقة الشرقية، بالمملكة العربية السعودية.

وتتكون ورود الصحراء من بلورات الجبس والتي تحتوي على حبيبات رمل على شكل وردي، في بنية وردية مميزة، وتكون معظم حبيبات الكوارتز ملصقة بواسطة بلورات الجبس التي تعرض بناءاً ليفياً.

إن المكونات الرئيسية لورود الصحراء بمنطقة عين دار هي أكاسيد السيليكا، والكالسيوم والكبريت، وتشتمل الأكاسيد الأخرى أكاسيد الصوديوم والبوتاسيوم بالإضافة إلى مقادير صغيرة من الحديد، والألمنيوم، والتيتانيوم، والمغنسيوم، والمنجنيز، والكروم، والنيكل، والفسفور.

إن المسامية والنفاذية العالية في منطقة عين دار سمحت للهجرة الأيونية السريعة أن تعزز النمو لورود الصحراء، وقد نمت بلورات ورود الصحراء في الرمل المفكك قرب سطح السبخة، ثم تركزت داخل الرمل على شكل بلورات وردية كبيرة مبعثرة، إن الحجم الكبير لمعظم البلورات ومكتنفات الرمل توحي بالإضافة والازدياد تحت ظروف هيدروكيميائية مستقرة.

Key Words: *Sabkha - sand roses - gypsum - quartz - fibrous - hypersaline-nucleation.*

ABSTRACT

Desert roses are crystals which usually take the form of rose petal. They have definite crystal shapes, and enclose sand grains. The desert roses were scattered along an area of about $500m^2$ in the Ayn Dar area, near Abqaiq, about 80km southwest of Ad Dammam, Eastern Province, Saudi Arabia.

They are made up of gypsum crystals included sand grains in the from of rosettes, with distinctive petal morphology. Most quartz grains are cemented by gypsum crystals which show a fibrous structure.

The main components of desert roses of Ayn Dar area are SiO_2, CaO and SO_3. Other oxides include Na_2O, K_2O and small amounts of Fe, Al, Ti, Mg, Mn, Cr, Ni and P.

High porosity and permeability in the Ayn Dar area permitted rapid ionic migration to promote the growth of desert roses. Desert roses crystals were grown in loose sand near the surface of the sabkha, and finally concentrated inside the sand as scattered large rose crystals. The large size of most crystals and the poikilitic inclusion of sand suggest accretion under stable hydrochemical conditions.

Introduction

Gypsum occurs sometimes in rose like crystal aggregates similar to barite. Gypsum rose with inclusions of sand particles have been found at some localities in the world. Attractive specimens have been collected from Oklahoma, California in U.S.A. and from Mexico, Canada, and Egypt [1].

Many sediments contain large crystals or clusters of gypsum crystals. Some of these grow in a friable sand matrix in a fashion similar to barite and calcite. These crystals may include a large volume of sand. A well-known examples are the large crystal aggregates from the Laguna Madre, Texas [2].

Desert roses are not flowers, but crystals which take the from of rose petals. They have definite crystal shapes, and enclose as much as 60 percent of sand. The studied desert roses were scattered along an area of about 500m2 in the new Ayn Dar village (Fig. 1). The area was a small sabkha located close to the supertidal zone of the Arabian Gulf, near Abqaiq about 80km southwest of Ad Dammam, Eastern Province, Saudi Arabia. Desert roses were taken from the surface. However, some of them have been observed at a depth of 30-50cm below the surface.

The sandy gypsum crystals (desert roses) range considerably in size, from 2-20cm in diameter interbedded with unconsolidated sand. Some larger ones are in excess of 30cm in diameter (Fig. 2).

The climate in the area can control the evaporate mineral facies and appears to be a critical factor in their presence and distribution [3,4]. The climate of the study area is typically desert. Mean temperatures range from 16°C in February to 37°C in August, with recorded extremes in the study area of about-2°C and 48°C. Rainfall is restricted to 4 months (Oct.- Jan.). The rainfall intensity is not uniform, but is of stormy nature. Evaporation rates are high, averaging over (76cm/month) during the summer [5].

The aim of this work was to investigate the mineralogy and chemistry of desert roses, and to shed some light on their formation.

Geoglogical Setting

A deposit of Quaternary sabkhah-related gypsum in the form of desert roses (sand roses) occurs in a small area, about 2km^2 of Ayn Dar (Lat. 26°, Long, 49° 23). The area is filled with eolian sand (Fig. 2). The figure shows a geologic map of Ayn Dar and surrounding areas in the Eastern province, Saudi Arabian [6]. The sabkhah deposit, mainly gypsum was almost eroded away in the Ayn Dar area. The figure shows also other formations; Hofuf, Dam and Hadruck Formations.

Where marine rocks occur, the Miocene and Pliocene succession can be subdivided into three formations which from the bottom up are Hadrukh, Dam, and Hofuf.

Hadrukh rocks are mainly green, grayish green, and gray, but red, brown, white, and pink colours are also common. Marly sandstone, sandy marl, sandy clay, and sandy limestone make up most of the unit; chert is common at some levels, and minor amounts of gypsum are also present.

The Dam Formation is pink, white, and gray marl and red, green, and olive clay with minor interbeds of sandstone, chalky limestone, and coquina.

The largest tingle exposure of the Hofuf Formation is superimposed on Ghawar field and almost perfectly mirrors the outline of that grant oil-filled anticline. The northern part of the structure is reflected in Hofuf beds at the surface by a prominent, dissected plateau capped by a resistant limestone layer. Hofuf rocks are imposed of conglomerate at the top and bottom of the Formation. White, in part impure sandy limestone. Moreover, Hofuf rocks contain arkosic sand with abundant orthoclase, microcline and quartz with igneous, metamorphic and sedimentary rock fragments. The source of the Hofuf rocks is the Arabian shield which consists of igneous, metamorphic and other rocks [7].

Materials and Methods

Thin sections of desert roses were made in the rock laboratory of the Geology Department, college of science, King Saud University. They were prepared in the absence of water to prevent excessive dissolution of water-soluble minerals. The thin sections were ground under acetone to prevent dehydration of gypsum to hemihydrite (bassanite). These thin sections were then studied under the polarizing microscope.

X-ray diffraction of about 15 samples was performed on a Siemens, D5000 diffractometer in the central laboratory of college of science, King Saud University. The CuKa radiation was operated at 40kV and 35mA, with a curved graphite crystal monochromator, automatic divergence slit and 0.015-counting for 2 seconds on each step. On-line peak search and match program are based on [8]. The identification of the mineral phases and the assignment of the Miller indices to the spacing were done by a computer programs.

Chemical analyses of desert roses was carried out in the laboratory of mineral sciences department, Smithsonian Institution, Washington, D.C., U.S.A.. All analyses were carried out using x-ray fluorescence techniques, except loss on ignition and SO_3 which were determined in the chemical laboratory of college of science, King Saud University, Riyadh, Saudi Arabia.

The analytical, data reduction, and correction procedures of the XRF analyses are similar to those given by [8].

The accuracy of the XRF method for major elements was estimated to be ± 2% and for trace elements to be 5-10%.

The loss on ignition (H_2O+) for all samples was calculated from weight loss after heating 2 gms of sample in vitreosil crucibles of 900-1000°C for about 2 hours.

Sulphate determinations (SO_3) were undertaken using the gravimetric technique [9 and 10].

Petrography

Sandy gypsum crystals are made up of numerous discoid sub individuals closely intergrown in sub parallel and radial arrangements. As accretion proceeds, the gypsum crystals grow and become more complex until they assume the characteristics of rosettes, with distinctive petal morphology (Fig. 4). The mutual relations of the gypsum crystal and the manner of growth are the basis for classifying these structures as desert roses (rosettes) rather than crystal aggregates [2 and 11].

Most gypsum crystals are colourless and belong to the satinspar crystalline variety. They occur as anhedral to subhedral aggregates, which show a fibrous structure. Extinction angle is parallel to (010) cleavage. Relief is low, refractive indices measured are $n\alpha = 1.520$, $n\beta = 1.522$, $n\gamma = 1.525$.

The gypsum crystals cleave readily on (101). However, traces of weak cleavages on (011) and (100) can be seen under the microscope. Thin sections of desert roses (Plates 1 and 2) show that gypsum forms between 45-50% of the sections. Quartz forms the remaining of the sections. Most quartz grains are floating and a very few of them have points of contact with their neighbours. They are included and cemented by gypsum. This may suggest that some sand grains had been pushed apart by mechanical force resulting from crystal growth of the gypsum. Most quartz occurs as coarse to medium monocrystalline grains, some crystal are poorly sorted, rounded to surrounded. Some of these grains have cracks and inclusions of heavy minerals, such as zircon, rutile, hornblende, magnetite and Cr-spinel. Heavy minerals form about 1-2% of the samples. Some quartz grains show wavy extinction. The poikilitic inclusions of desert roses are a characteristic feature. Such feature develops only when the crystal growth rate exceeds the maximum rate of sand displacement [11].

Results

X-ray diffraction analysis of about 15 samples of desert roses revealed that they consist simply of a mixture of gypsum and quartz. Both minerals were positively identified and determined by on-line peak search and match program [8]. X-ray diffractogram is presented in fig. 5.

Table 1 shows the chemical analyses of desert roses, including XRF and wet chemical analyses.

The main components of desert roses are SiO_2, CaO and SO_3. however, the presence of Na and K in the desert roses can be attributed to the presence of halides in ionic form during the initial stage of precipitation. Such elements may also contribute to precipitation of desert roses. The presence of Fe, Al, Ti, Mg, Ti, Mn, Cr, Ni and P indicates that these elements are scattered in desert roses, mainly in quartz as a components of heavy minerals and as impurities in gypsum.

K_2O is high and can explained by the occurrence of kaolinite in the mineral assemblage (Fig. 5). The high Cr and Ni content can be explained by the presence of heavy minerals, such as magnetite and probably Cr-spinel.

Table 1

XRF analysis of Desert Roses, Saudi Arabia

	DR21	**DR22**	**DR23**
SiO_2	43.01	43.09	44.01
Al_2O_3	2.63	2.71	2.67
Fe_2O_3	0.52	0.54	0.54
FeO	0.10	0.10	0.12
MgO	0.56	0.54	0.57
CaO	21.00	21.00	21.00
SO_3	24.61*	25.00*	25.00*
Na_2O	0.25	0.27	0.25
K_2O	1.12	1.14	1.16
TiO_2	0.11	0.10	0.10
PsO_5	0.03	0.03	0.03
MnO	0.01	0.01	0.01
Cr_2O_3	0.06	0.06	0.06
NiO	0.06	0.06	0.06
L.O.I	4.09*	5.90*	4.95*
Sum	98.16	100.55	100.53

Chemical laboratory of mineral sciences, Smithsonian Institution, Washington, D.C., U.S.A.

* Wet chemical analyses, in the chemistry Department, King Saud University, Riyadh, Saudi Arabia.

Discussion

This paper reports for the first time the mineralogy and chemistry of desert roses in Ayn Dar area, Eastern Province, Saudi Arabia. The study of desert roses contribute to the understanding of the crystal morphology of desert roses in the $CaSO_4$-H_2O system and the conditions of formation in the arid climate of Saudi Arabia. The climate and presence of detrital quartz and other elements, such as Na and K may control the rates of certain physical and (or chemical processes, such as evaporation and nucleation aspects) in the evaporite system [12 and 13].

Many researchers have studied the environment of the gypsum precipitating from Sabkhas and suggested that gypsum will be the phase precipitated from sabkha brines in the system $CaSO_4$-H_2O [14,15,16,17, 18 and 19]. Other workers have shown that desert roses which developed in sandy deposits tend to incorporate sand grains [20, 21, 22, 23, 24 and 25]. Evaporation of water on a playa or sabkha and downward movement of the dense hypersaline water into sediment below, will result in the formation of gypsum crystals [2 and 13]. Sodium probably stimulates the development of the desert rose habit by retarding growth of the (111) face at the expense of (102) [2 and 12]. Another important experimental study on gypsum formation is the determination of the parameter that control the nucleation density of crystals. Cody and Cody [26] determined that, with increased NaCl content in the brine, nucleation density decreased producing larger crystals. In a 5% NaCl solution, the nucleation density was 10 times less than that in an NaCl-free solution.

High porosity and permeability in the sand beds of Ayn Dar area would permit rapid ionic migration to a few large centers of crystallization and can promote growth of desert roses. The abundance of included sand in some buried desert roses indicates that they were formed in sediments composed almost entirely of sand. These sandy gypsum crystals may have been deposited originally at or near the surface as thin beds of small crystals. Finally, such crystals become concentrated in the form of scattered large desert rose crystals.

It is suggested that desert rose crystals of Ayn Dar area grew in lose sand near the surface of the sabkha, so that confining pressures were not large. The quartz grains included in the desert roses show little contacts, indicating very little evidence of displacement. The large size of most gypsum crystals and the poikilitic inclusion of quartz grains within them suggest that accretion occur under stable hydrochemical conditions.

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REFERENCES

[1] **Sanborn, W.B. 1976.** Oddities of the Mineral World. Van Nostrand Reinbold Co., New York, 142 pp.

[2] **Masson, P.H., 1955.** An occurrence of gypsum in South-west Texas. J. Sed. Petrol. 25, 72-77.

[3] **Kinsman, D.J.J., 1976.** Evaporates: Relative humidity control of primary mineral facies. J. Sedim. Petrol., 46; 273-79.

[4] **Smith, C.L., 1982.** Reconnaissance investigation of evaporates and brines of the Eastern Province, Open-file report, USGS-OF-02-10.

[5] **Williams, R.O., 1979.** ARAMCO meteorologic and oceanographic databook for the Eastern Province of Saudi Arabia: Dhahran, environment Unit, Technical services Dept., Arabian American Oil Co., 133 p.

[6] **Steineke, M., Harriss, T.F., Parsons, K.R., and Berg, E.L., 1979.** Geologic map of the Western Arabian Gulf quadrangle, Kingdom of Saudi Arabia, GM-208A, Directorate General of Mineral Resources, Jeddah, Saudi Arabia.

[7] **Powers, R.W. Ramirez. L.F., Redmond, C.D., & Elberg, E.K., Jr., 1966.** Sedimentary geology of Saudi Arabia Peninsula, U.S. Geological Survey Professional Paper 560-D: D1-D147.

[8] **Smith, D.G.W. and Leibovitz, D.P., 1986.** Midldent: A database for minerals and a computer program for their identification. Canadian Mineralogy, V. 24, 695-708.

[9] **Reed, S.J.B., 1990.** Recent development in geochemical microanalysis, Chemical Geology, 83; 1-9.

[10] **Belcher, R. and Nutten, A.J., 1970.** Quantitative Inorganic Analysis. Butterworth and Co. (Publishers) Ltd., London, 3rd. Edition.

[11] **Pettijohn, F.J., 1975.** Sedimentary rocks, 3rd edition; Harper & Row Publisher, New York, 628 p.

[12] **Kastner, M. 1970.** An inclusion hourglass pattern in synthetic gypsum. Am. Mineral. 55, 2128-2130.

[13] **Edinger, S.E., 1973.** The growth of gypsum. An investigation of the factors which affect the size and growth rates of the habit faces of gypsum. J. Cryst. Gr. 18,217-224.

[14] **Zen, E-An, 1965.** Solubility measurements in the System $CaSO_4$-NaCl-H_2O at 35-, 50- and 70-C and one atmosphere pressure. J. Petrol. 6, 124-164.

[15] **Braitsch, O., 1971.** Salt Deposits: Their origin and composition, Springer-verlag, Berlin.

[16] **Butler, G.P., 1969.** Modern evaporate deposition and geochemistry of coexisting brines, the sabkha, Trucial coast, Arabian Gulf, J. sedim. Petrol., 39, 70-98.

[17] **Patterson, R.J. and Kinsman, D.J.J., 1977.** Marine and continental groundwater sources in an Persian Gulf coastal sabkha, in S.H. Frost, M.P. Weiss and J.B. Saunders, eds., Reefs and related carbonates ecology and sedimentology; AAPG, p. 381-399.

[18] **Schreiber, B.C., 1988.** Evaporates and Hydrocarbons. Columbia Univ. Press, New York, 475 p.

[19] **Shearman, D.J., 1966.** Origin of marine evaporates by diagnosis. Inst. Mining Metallurgy, Trans., Sec. B75, 208-215, New York.

[20] **Sonnenfeld, P., 1984.** Brines and Evaporates, Academic Press, New York, P. 149-161.

[21] **Al-Kofahi, M.M., Hallak, A.B., Al-Juwair, H.A. and Saafin, A.K., 1993.** Analysis of desert rose using PIXE and RBS techniques. X-Ray Spectrometry, vol. 22, 23-27.

[22] **Hardie, L.A. and Eugster, H.P., 1971.** The depositional environment of marine evaporates; a case for shallow, clastic accumulation: Sedimentology, V. 16, 187-220.

[23] **Murray, R.C. 1964.** Origin and diagenesis of gypsum and anhydrite J. Sed. Petrol., 34, 512-523.

[24] **Shearman, D.J., 1981.** Displacement of sand grains in sandy gypsum crystals. Geol. Mag. 118 (3), 303-306.

[25] **Watson, A., 1985.** Structure, chemistry and origins of gypsum crusts in southern Tunisia and Central Namib Desert. Sedimentology, 32: 855-875.

[26] **Cody, R.D. & Cody, A.M., 1988a.** Gypsum nucleation and crystal morphology in analog saline terrestrial environments. J. Sedim. Petrol., 58, 247-255.

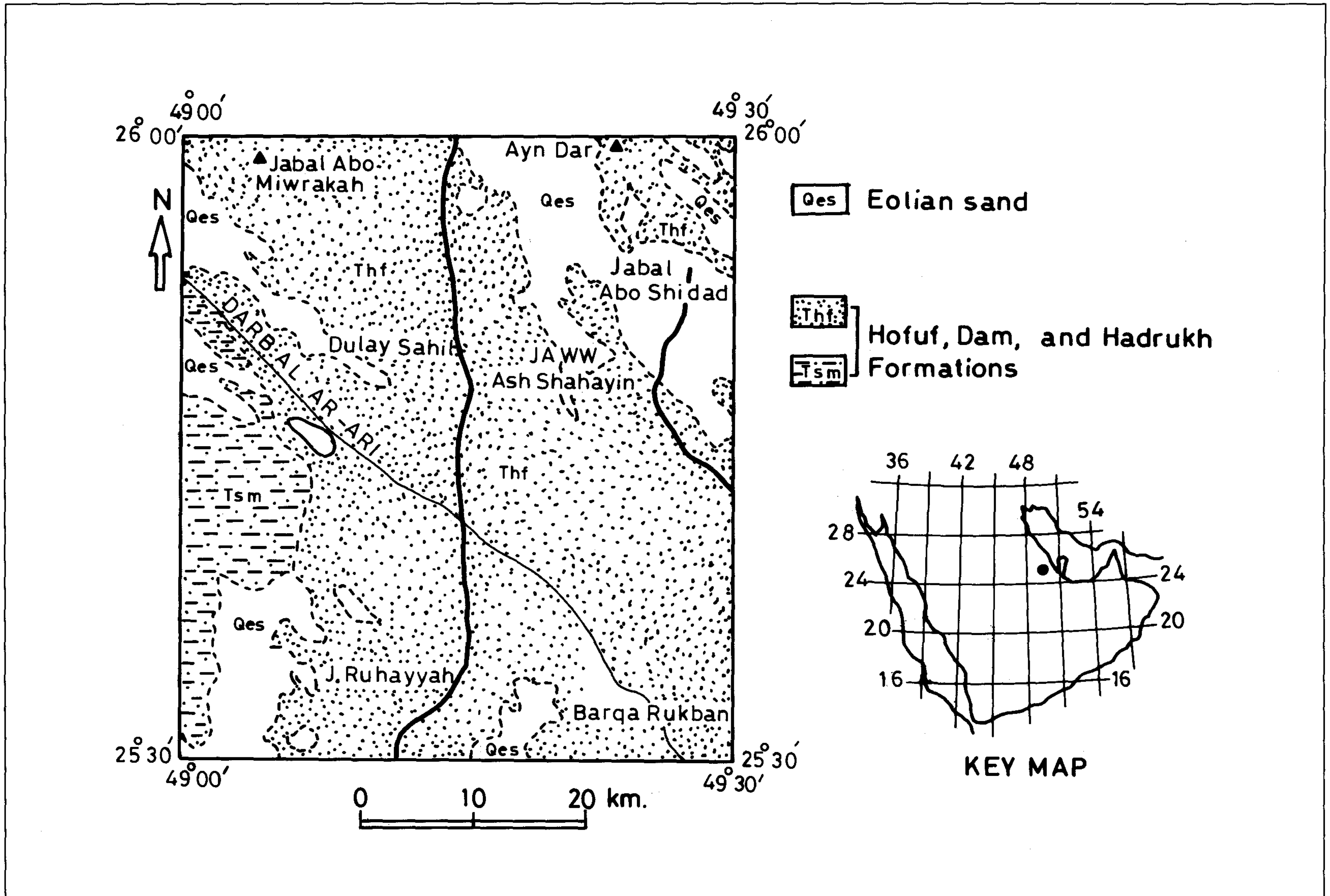

Fig. 1: Geologic map of Ayn Dar and Surrounding areas, Eastern Province, Saudi Arabia (Modified after Steineke, M. and others, 1979).

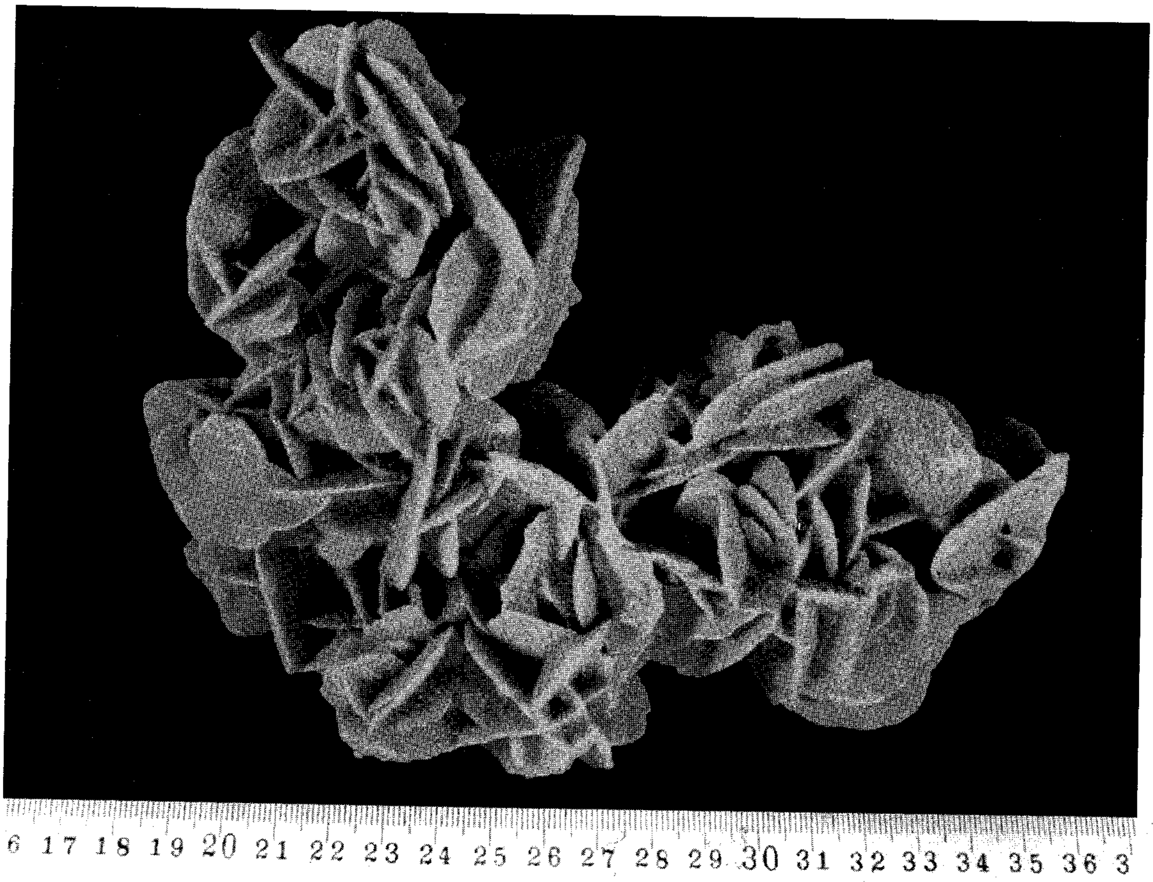

Fig 2: Typical desert roses in the Ayn Dar area, Eastern Province, Saudi Arabia.

Fig 3: The old sabkha of Ayn Dar area, looking West.

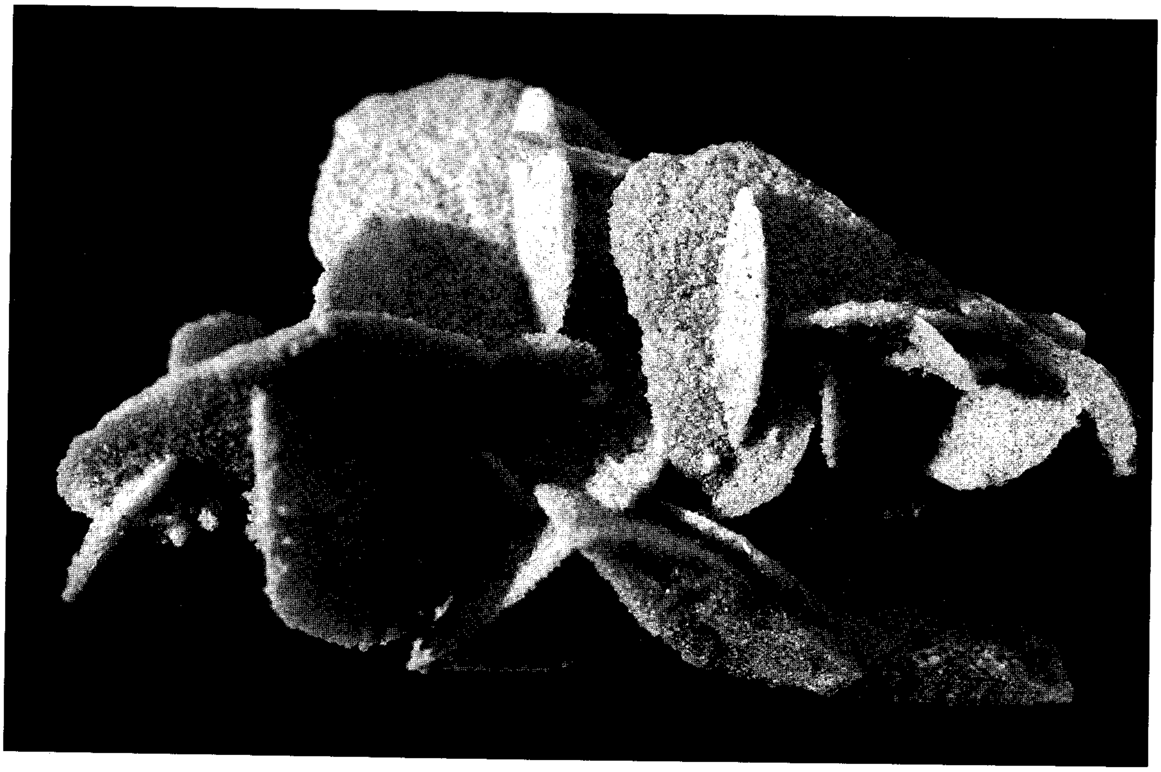

Fig 4: Desert roses with luster-mottled appearance by the included sand grains. Notice the distinctive petal morphology.

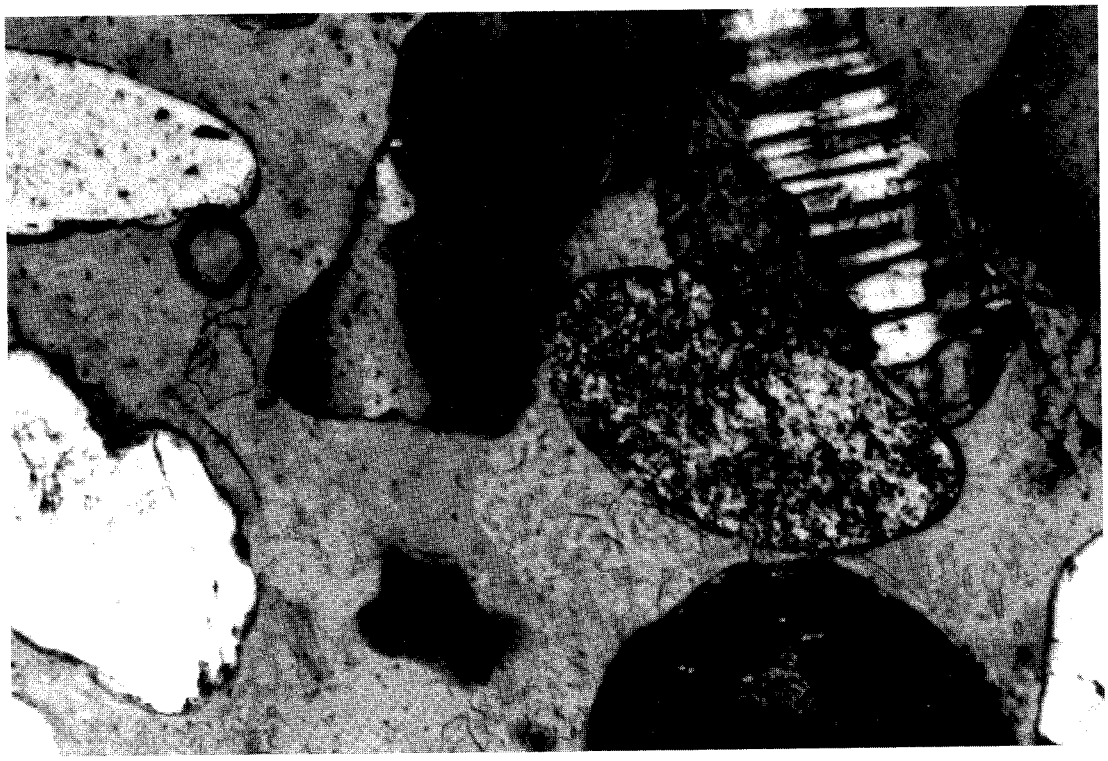

Plate 1: Quartz grains cemented by gypsum.
Notice the cracks in the quartz grains (crossed polars X 25).

Plate 2: Scattered quartz grains with some point contacts.
Notice the heavy mineral grains inside the quartz (crossed polars X25).