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Depositional Environments of The Buwaib – Biyad – Wasia Rocks Deduced by X–Ray Diffraction Analysis

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Several samples of shales and clays from both the borehole, PW_3 and the outcrop of Buwaib, Biyad and Wasia, in Central Saudi Arabia were analysed to determine first, the clay and non-clay mineral composition and second to reveal their possible depositional environments. The diffracted peaks of these samples show that kaolinite is the predominant clay mineral group in the Biyad-Wasia sediments and in perfectly to very well crystallized form. Other clay minerals which followed in amount are illite, montmorillonite and mixed-layer clay respectively. The predominance of kaolinite in the Biyad-Wasia sediments has suggested a continental and / or non-marine type of environment for these sediments. This is also supported by the fact that this kaolinite is perfectly well crystallized. The presence of both illite and montmorillonite are possibly related to the specific physico – chemical conditions which were obtained during processes of deposition and diagenesis. Moreover, the trace amounts of montmorillonite and illite as revealed by a few Buwaib carbonate samples may point to formation in a marine environment.

Several samples of shale and clay from the borehole, PW_3 (Fig. 1) selected for clay mineral determination, both qualitatively and quantitatively. A few samples from the outcrop (Fig. 1) of Buwaib (carbonate) and Biyad-Wasia (shales and clays) were also analysed to determine the clay and non-clay mineral composition.

Tables 1 and 2 show the summarized X-ray analysis results for the borehole and the outcrop samples respectively. In the borehole, the Biyad, Shu'aiba, and Wasia samples contain mainly kaolinite, illite, montmorillonite and mixed-layer clay-minerals together with significant amounts of non-clay minerals, *e.g.* quartz, calcite, dolomite, feldspars, and iron oxides, (Table 1). The outcrop samples of the Biyad and Wasia Formation display comparable clay and non-clay mineral assemblages, together with gypsum, (Table 2). The Buwaib carbonate samples also reveal some clay content (mainly kaolinite; Table 2). Figures 2 to 6 show the X-ray diffraction patterns of a few of the clay and carbonate sediments analysed.

Procedures

(a) *Apparatus*

A total of forty five shale and mudstone samples (mainly from borehole, PW_3, the Buwaib section near Khashm Ath Thamama, plus selected samples from Biyad-Wasia logged sections) were analysed on Philips X-ray diffractometry equipment. This apparatus comprises a generator (PW 1010, 1 kilowatt generator) updated with newer sample chamber, detector and electronic panel, a wide range goniometer (PW 1050), X-ray tube shield converted to PW 1316/00, with a proportional detector probe (PW 1965/20/30/40) linked to Philips (PM 8220) dual pen recorder with circuit panel PW 1370/05 (high voltage supply-amplifier/analyse rate meter counter-timer goniometer supply recorder).

The X-ray tube with a copper target is used to an accelerating potential of 36 KV and a current of 24 MA. A nickel filter is introduced into the X-ray beam to select CUK α radiation.

The goniometer is set at a speed of 1° 2θ/min., with a chart speed on the recorder equivalent to 4cm/min. Water pressure is 60 lbs/in^2. Furthermore, air dried samples are run from $2°2\theta$ to $40°2\theta$ whilst glycolated and heated ones up to $15°2\theta$.

(b) *Preparation of powder and oriented grain mounts*

Each of the selected samples was pulverized with a pestle and morter, taking care not to make the crushing process too prolonged and vigorous, which can produce an amorphous or allophanelike material (Fieldes *et al.*, 1966), because this destroys the ordered crystalline structure (*i.e.* crystallinity) of many clay minerals. The pulverized sample was passed through a 200-mesh sieve (3.720) into the collecting pan. Some 15 grams of the sub-200 mesh material was then dispersed in a liter cylinder and distilled water added to bring it up to exactly 1000ml. Then the dispersed mixture was stirred vigorously with a long glass rod or a rotary blender, and left to settle for an hour and forty five minutes, (timing starts as soon as stirring stops), Folk (1968). At then the top 10cm was withdrawn by pipette and collected in a glass beaker. The collected dispersion was centrifuged to separate the clay from the water, which was then decanted, leaving the thick clay fraction inside the centrifuge tube.

An eye-dropper filled with distilled water was used to give an intermediate clay solution (*i.e.* a slurry). The slurry was drawn by the eye-dropper and squeezed gently and evenly on a prepared X-ray glass slide, then the slide was left to dry completely at room temperature when it was ready to be X-rayed.

The clay-covered glass slide was run first untreated (*i.e.* air dried) in the X-ray diffractometer over the range 2° 2θ to 40° 2θ. The slide was then introduced into the vapour from an ethylene glycol bath for one hour at 60°C (Brunton 1955, and Brindley in Brown 1961), then X-rayed over the range 2° 2θ to 15° 2θ, and finally the slide was placed in an electric furnace and maintained there at 550°C for two hours, and again X-rayed over the range 2° 2θ to 15° 2θ.

These X-ray preparation techniques have been adapted from Brindley (1961). Gibbs (1965), Folk (1968), Carroll (1970) and Gibbs (1971).

Discussion

The reflected peaks shown in Fig. 2 to 6, together with Table 1 indicate that kaolinite is the predominant clay mineral group in the Biyad, Shu'aiba and Wasia sediments, and are followed in amount by illite, montmorillonite and mixed-layer clays respectively.

Quantitative approximations based on peaks height ratios have been determined, using the method of calculation devised by Biscaye (1965) and these values are given in Tables 3 and 4. This quantitative approximation also suggests that kaolinite is the most prominent of all the clay minerals present in the Biyad, Shu'aiba, and Wasia sediments. Furthermore, kaolinite is also the dominant clay mineral in carbonate samples (Tables 2 and 4). Crystallinity measurements have been produced by the method of Jacobe (1974), and Tables 3 and 4 show such measurements. These indicate that most of the kaolinite present in these sediments is perfectly to very well crystallized (Tables 3 and 4).

Kaolinite is recognized here by its well defined first and second order basal reflections (or peaks) at 7.1A° and 3.5A° respectively. These 7.1 and 3.5A° peaks are also occupied by chlorite (Weaver 1967, p. 47) but distinction between kaolinite and chlorite is based on heating to 550°C for 1 hr giving rise to collapsed or destroyed kaolinite peaks (Brindley, in Brown 1961, Ch. II, p. 85 and see Fig. 2 to 5). However, on glycolation, kaolinite peaks remain unaffected. As a further distinction, kaolinite gives a small peak at 2.38A° which is usually absent or very weak in the chlorite pattern (Weaver 1967, p. 47). Examples of the complete range of kaolinite diffraction patterns are given by Grim (1953, p. 50) and Murray and Lyons (1956).

Grim (1968) indicated that illite has a 10-A° C-axis spacing which shows substantially no expanding-lattice characteristics. Illite is identified in the present study by its distinct peak at 9.9A°, and since it is essentially a non-expanding clay mineral, the peak remains unaffected on glycolation, whilst on heating this peak is sharpened to 10.0A° (Fig. 2 to 5).

Montmorillonite is here recognized by its peak between 14 to 15A° when untreated (or air dried). When treated with ethylene glycol a split peak is developed; the montmorillonite peak expands to near 17A°, whilst that of the mixed layer remains in its original place. However, on heating to 550°C, both peaks are collapsed and may retreat to the illite spacing 10.0A°, which is indicated by the enhancement of the previous illite peaks (Fig. 2 to 5).

The only recognized mixed-layer minerals commonly encountered in this study are predominantly characterised by random or irregular interstratification of layers. These mixed-layer minerals are composed of illite and montmorillonite layers which give basal spacings between those of the two components (Fig. 2 to 5). Thus this peak occurs between 10 and 15A° on the untreated (air dried) reflection and on glycolaction expands between 10 and 17A°. However, on heating to 550°C, the mixed-layer peak is almost completely collapsed at the zone of 15A° and the illite part may retreat to 10A° (*i.e.* the spacing for illite).

Keller (1953, p. 94) has indicated that in general heating destroys or reduces the kaolinite basal spacing, sharpens that of illite and thus aids in the detection of chlorite. Accordingly, this has been clearly recognized in the diffracted kaolinite peaks in the Biyad-Wasia clay analyses (Fig. 2 to 5).

Authors like Glass (1958); Pryor and Glass (1961) and Weaver (1960 and 1961) have generally considered that kaolinite to be dominant in fluviatile environments. They also indicated that illite, montmorillonite and mixed-layer are most abundant in sediments of marine environments origin. Moshrif (1976) has indicated that the Biyad and Wasia sediments in Central Saudi Arabia are fluvial deposits. This was based on detailed studies of grain size and surface textural analyses and also several recognized fluvial cycles (Moshrif 1976). It is plausible now to suggest that the abundant kaolinite mineral, present in these formations, is formed under fluvial conditions and the small amount of both illite and montmorillonite were derived from older sedimentary rocks, perhaps were formed under marine environments. Thus, it is also concluded here that both the Biyad and Wasia sediments are fluvial deposits.

Keller (1956 and 1970) has summarised the environmental conditions common to the genesis of the kaolinite, montmorillonite and illite groups of minerals. He has indicated that kaolinite probaby forms from weathering of pre-existing rocks. This clay mineral requires formative conditions involving precipitation exceeding evaporation, intense leaching (*i.e.* not stagnant water and permeable rocks), and the removal of Fe(iron) from the clay-forming system, *i.e.* oxidationof Fe to Fe_2O_3 or to FeS_2. Also it requires an excess supply of H^+ ions with the removal of Ca^{2+}, Mg^{2+}, Na^+ and K^+ ions. Moreover, he indicated that the high Al : Si ratio, in kaolinite implies some removal of silica from the original rock-forming silicates. Kaolinite will develop through weathering of granite, mafic rocks and also from volcanic ash. Based on detailed investigation of both paleocurrent vectors and heavy mineral analyses, Moshrif (1976) suggested that most of the Biyad-Wasia sediments were derived from the Arabian Shield (*i.e.* igneous and metamorphic rocks), lies to the west of these formations. Thus, it seems very probable that the kaolinite of the Biyad-Wasia were developed from the weathered products of their parent rocks in their fluvial depositional environments.

In his study of the Pennsylvanian Cheltenham formation of Missouri, Keller (1956, p. 2707) has concluded that in passing from a non-marine to a marine environment, the clay assemblages change from a well-crystallized kaolinite-rich suite, through a good to moderately crystallized suite, and finally to a largely illitic suite. The kaolinite present in the Biyad Wasia sediments is perfectly to very well crystallized (Table 3 and 4).

The environment of formation of the montmorillonite group of clay minerals has also been summarized, by Keller (1956 and 1970) as represented by conditions where there is no excess of H^+ ions, leading to retention of Mg^{2+}, Ca^{2+} and Fe ions, where evaporation exceeds precipitation (*i.e.* semi-aridity), with stagnant water (ash, tuff in lakes and ocean), and poor leaching. Montmorillonite thus requies alkaline conditions, retention of Fe ions in the clay-forming system, producing a high Si : Al ratio, through retention of silica.

The most obvious conditions which favour the formation of illite are the retention of M (metallic) ions, especially K^+ and Ca^{2+} and no excess of H^+ ions. Moderate rainfall, *i.e.* alternation of wet and dry conditions, the presence of $CaCO_3$ and marine conditions are also important. Moreover, illite resembles montmorillonite in requiring a high Si : Al ratio (Keller 1956 and 1970).

Furthermore, Keller (1946, 1953, 1956) related the modification or development of clay minerals to ''a set of physicochemical conditions'' which occur during processes of deposition and diagenesis rather than to a specified environment, *i.e.* ''non-marine'' or ''marine''. Also Powers (1958) referred to the importance of diagenetic alteration of clay minerals, due to the major chemical changes that have occurred during and after the deposition of sediments. Grim (1968) postulated that most clay minerals are ''authigenic'' and are developed or effectively modified in their depositional environments. He also indicated that changes in clay-mineral composition result from changes in conditions of deposition rather than diagenetic changes.

Conclusion

The present study suggests that the recovered clay minerals, *i.e.* kaolinite, illite, and montmorillonite, are authigenic in origin and have formed from the weathered products of the parent rocks (*i.e.* igneous and metamorphic rocks of the Arabian Shield) in their depositional environments. This idea is based on the fact that all the Biyad, Shu'aiba and Wasia analysed samples have shown similar clay mineral compositions, *i.e.* there is no change in conditions of depositions throughout the Biyad-Wasia formations, and subsequently there is no idication of diagenetic changes.

Thus the prevalent kaolinite may have formed from all source sediments when weathering solutions were acidic to neutral in flowing water (*i.e.* river) and leaching was sufficient to remove cations, such as Fe, K, Mg and Ca, taken into solution. Illite was probably produced from volcanic or igneous material, when the solutions were basic, with moderate leaching and with retention of metallic ions, particularly potassium and calcium. Under nearly the same conditions, montmorillonite was developed, in stagnant water, *i.e.* perhaps in marine conditions, where poor leaching and Mg^{2+} and Ca^{2+} and iron ions were present.

Since kaolinite is the predominant clay mineral found in the Biyad-Wasia sediments (Tables 1 and 2), this suggests a continental and/or non-marine-type of environment for the Biyad-Wasia sediments. The fact that this kaolinite is perfectly very well crystallized (Tables 3 and 4) also supports formation in a non-marine environment, and is in accord with the views of Keller (1956, p. 2707).

The presence of both illite and montmorillonite (Tables 1 and 2) are possibly related to the specific physicochemical conditions which were prevailed during processes of deposition and diagenesis. However, the trace amounts of montmorillonite and illite as revealed by a few Buwaib carbonate samples (Table 2) may point to formation in a marine environment.

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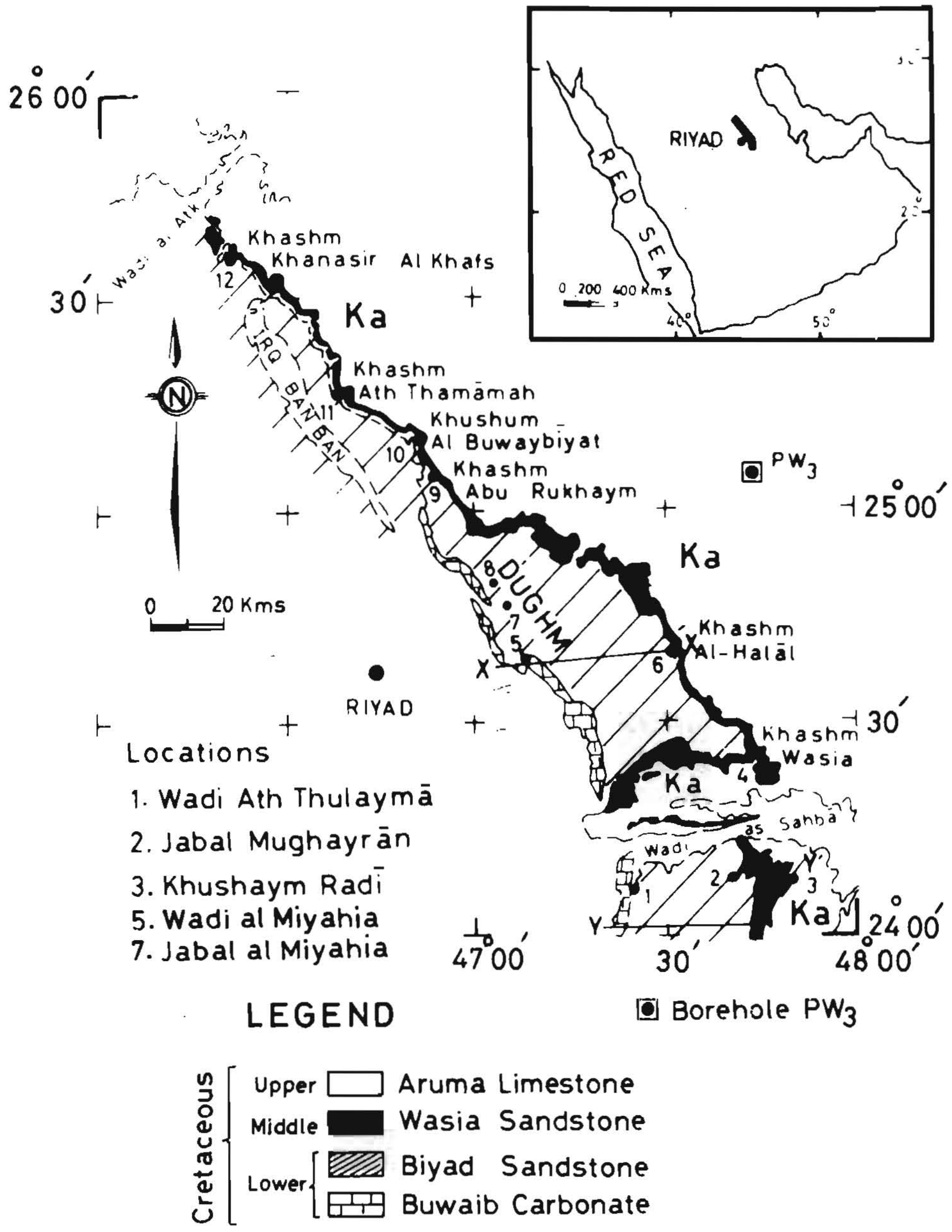

Fig. 1. Locality map shows general distribution of Cretaceous rocks in Central Saudi Arabia. Inset (upper right) indicates location of studied area in the Arabian Peninsula.

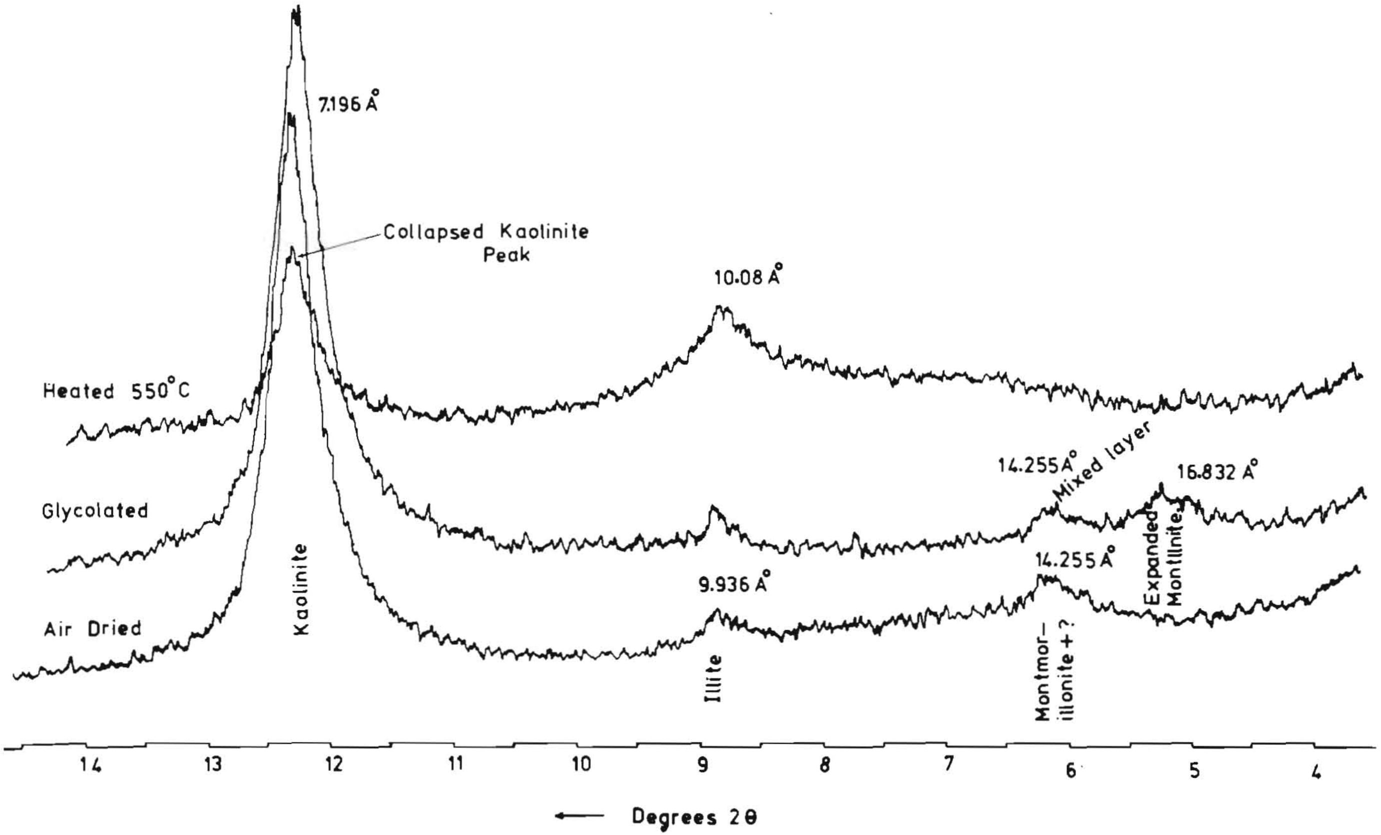

Fig. 2. X-ray diffractions pattern of oriented clay minerals. Borehole PW_3, sample no. 178–179.

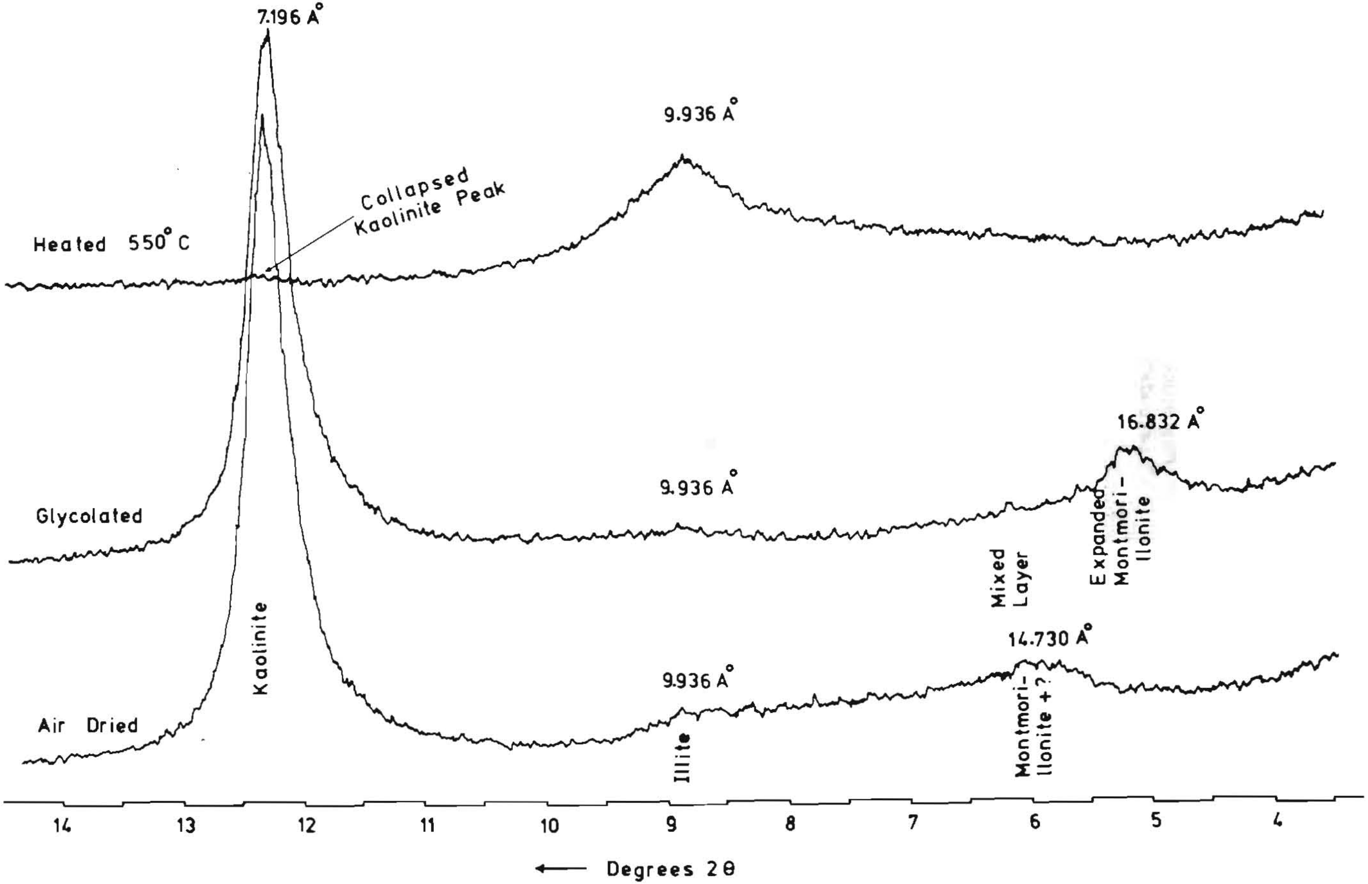

Fig. 3. X-ray diffraction pattern of oriented clay minerals. Borehole PW_3, sample 196–197.

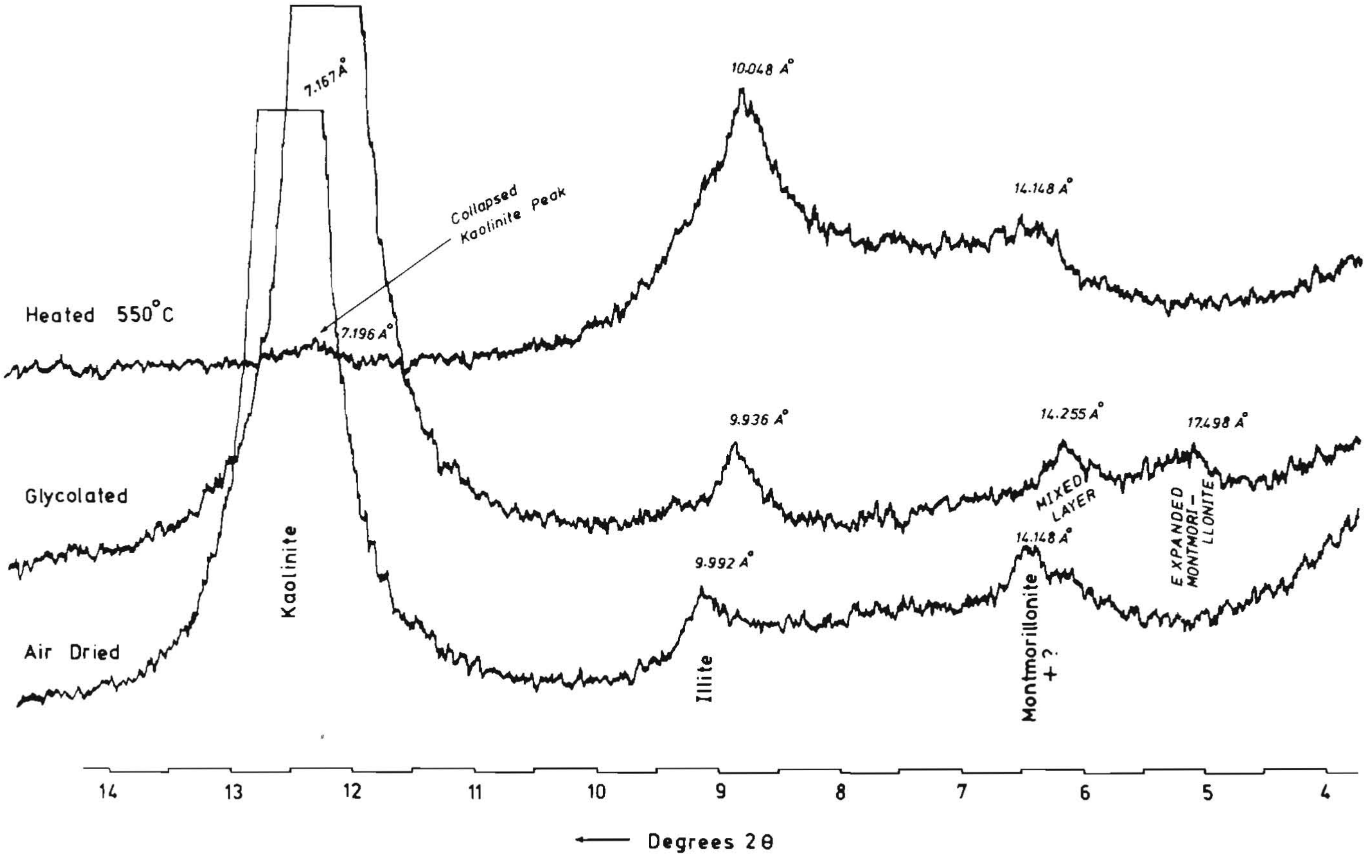

Fig. 4. X-ray diffraction pattern of oriented clay minerals. Borehole PW_3, sample 370–371.

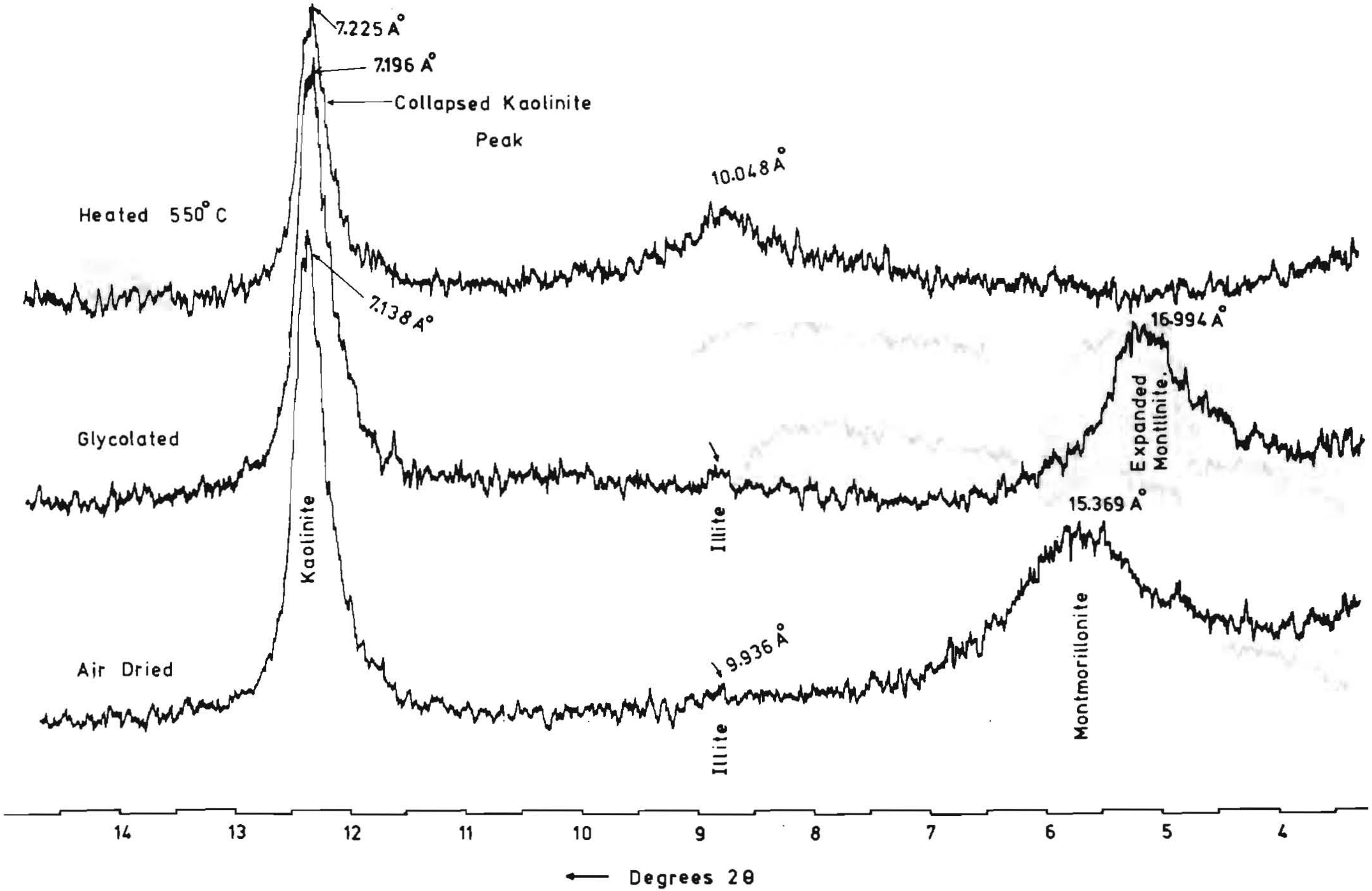

Fig. 5. X-ray diffraction pattern of oriented clay minerals. Borehole PW_3, sample 706–707.

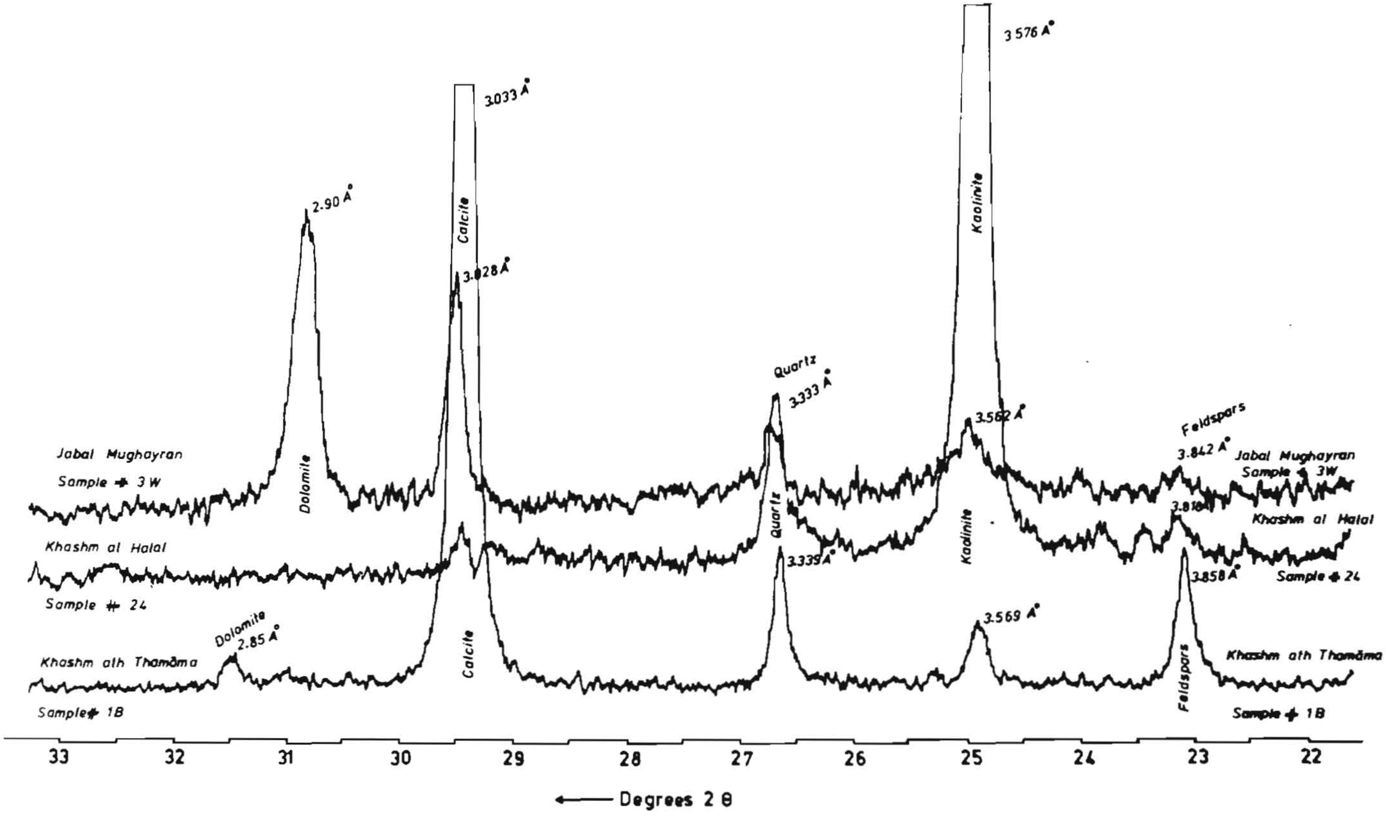

Fig. 6. X-ray diffraction pattern of selected carbonate sediments.

Table 1. Summarized qualitative and semi-quantitative data on clay and non-clay mineral composition of Biyad-Wasia Formation samples, from X-ray diffraction methods. Samples are selected from Borehole, PW_3.

Reference No.		Non-Clay Minerals					Clay Minerals				Formation
Serial No.	Selected Samples Depth (in m)	Quartz	Calcite	Dolomite	Feldspars	Iron-oxides	Kaolinite	Illite	Montmor-illonite	Mixed layer	
1	168–169	3	2	4	6	6	5	–	–	–	WASIA
2	169–170	3	1	4	6	6	4	–	–	–	
3	170–171	5	–	–	–	–	4	–	–	–	
4	172–173	4	3	–	6	–	3	6	–	–	
5	174–175	5	–	–	–	–	1	6	5	6	
6	178–179	4	6	–	6	–	1	6	5	6	
7	181–182	5	6	6	6	–	1	6	6	6	
8	183–184	5	–	–	–	–	1	6	6	6	
9	186–187	6	–	–	–	–	2	6	6	6	
10	188–189	5	–	–	–	–	1	6	5	6	
11	190–191	6	–	–	–	–	1	6	6	–	
12	192–193	6	–	–	–	–	2	6	6	6?	
13	194–195	6	–	–	–	–	1	6	6	–	
14	196–197	3	6	–	–	–	1	6	5	6?	
15	208–209	1	–	–	–	6	1	6	4	6?	
16	362–363	3	–	–	–	–	1	6	6	–	SHUAIBA
17	365–366	3	–	–	–	–	1	6	5	6	
18	367–368	3	–				2	5	4	6	
19	369–370	3	–	–	–	–	1	5	4	6	
20	370–371	3	–	–	–	–	1	5	4	6	
21	702–703	1	–	–	–	6	3	–	–	–	BIYADH
22	704–705	1	–	–	–	–	2	–	5	–	
23	706–707	1	–	–	–	–	1	6	5	–	
24	710–711	1	–	–	–	6	2	6	6	–	
25	712–713	1	–	–	–	6	4	6	5	6	
26	714–715	1	–	–	–	6	1	6	6	6?	

Note: 1 = Extremely abundant; 2 = Abundant; 3 = Common; 4 = Fairly common; 5 = Rare; and 6 = Trace.

Table 2. Summarized qualitative and semi-quantitative data on clay and non-clay mineral composition of Buwaib, Biyad and Wasia Formation samples, from X-ray diffraction methods. Samples are selected from the outcrops.

Reference Nos.		Non-Clay Minerals					Clay Minerals				Remarks*
Series No.	Location and Sample No.	Quartz	Calcite	Dolomite	Feldspars	Iron-oxides	Gypsum	Kaolinite	Illite	Montmor-illonite	
1	5	3	–	–	–	–	4	1	5	6	A
2	12a	3	–	–	–	–	–	1	5	5	
3	3W	5	3	2	6	–	–	4	6?	–	B
4	2W	5	6	2	6	–	–	4	5	–	
5	1W	5	1	6	6	–	–	4	6?	–	
6	9Wa	6	–	–	–	6	–	3	–	–	C
7	24H	4	6	–	6	–	3	1	5	–	D
8	13H	4	–	–	–	–	–	3	6	–	
9	13aB	4	–	–	–	–	–	1	6	4	E
10	B1	5	1	–	4	–	–	1	6	6	F
11	B2	6	1	6	4	–	–	–	–	–	
12	19C	–	1	6	4	–	–	–	–	–	G
13	17C	–	1	6	4	–	–	5	–	–	
14	15C	–	1	6	4?	–	–	5	–	–	
15	10C	–	1	6	4	–	–	–	–	–	
16	9C	5	1	6	4	–	–	1	6	6	
17	6C	6	1	6	3	–	–	5	–	–	
18	4C	–	1	6	4	–	–	–	–	–	
19	1C	4	1	6	4	–	–	4	6?	–	Buwaib

Note: 1 = Extremely abundant; 2 = Abundant; 3 = Common; 4 = Fairly common; 5 = Rare; and 6 = Trace.

* Samples selected from:

A – Biyad SS. at y-y' section, South Wadi as Sahba.
B – Locality 2; Jabal Mughayran (Biyad).
C – Wasia SS, Section at Locality 12, Kh. Al-Khanasir.
D – Locality 6, Kh. Al-Halal.
E – Locality 10, Kh. Al-Buwaybiyat.
F – Buwaib Ls. at y-y section: South Wadi as Sahba.
G – Buwaib Ls. Sec. at Locality 11, Kh. Ath-Thamama.

Table 3. **Summarized quantitative estimates (based on peak height) of clay minerals present in shales and mudstone beds, within the Biyad and Wasia Formations; samples are selected from the Borehole, PW_3.**

Series No.	Selected Samples Depth (in m.)	Peak Height				Peak Width			
		K	I	M	Mixed Layer	K	I	M	Mixed Layer
1	168–169	2.1	–	–	–	1.3	–	–	–
2	169–170	3.2	–	–	–	1.9	–	–	–
3	170–171	4.2	–	–	–	1.4	–	–	–
4	172–173	5.6	1.8	–	–	1.5	7.7	–	–
5	174–175	12.8	0.7	1.1	0.5	1.4	1.5	2.9	2.0
6	178–179	14.0	1.0	1.3	0.9	1.4	2.3	3.0	1.5
7	181–182	9.9	0.5	0.8	0.6	1.3	1.5	2.5	1.3
8	183–184	13.5	0.6	1.0	0.7	1.4	2.4	2.5	1.5
9	186–187	7.5	0.3	0.5	0.3	1.4	1.9	2.1	1.5
10	188–189	9.8	0.5	0.9	0.5	1.4	1.5	2.6	1.4
11	190–191	10.8	0.3	0.3	–	1.4	1.5	2.5	–
12	192–193	8.9	0.3	0.3	0.1	1.3	1.8	2.6	1.3
13	194–195	16.5	0.3	0.4	–	1.4	1.7	2.5	–
14	196–197	16.5	0.6	0.9	0.2	1.3	2.3	3.0	0.6
15	206–207	11.10	0.6	3.9	–?	0.9	1.3	4.2	–?
16	362–363	12.4	1.0	0.8	–	1.4	1.6	3.1	–
17	365–366	6.8	0.4	0.4	0.7	1.5	2.0	3.0	2.0
18	367–368	7.8	0.3	0.5	0.2	1.3	1.8	3.0	1.2
19	369–370	9.0	0.3	0.45	0.40	1.05	1.7	2.5	2.2
20	370–371	11.0	0.4	0.40	?	1.05	2.0	3.2	?
21	702–703	5.2	–	–	–	0.8	–	–	–
22	704–705	9.0	–	1.4	–	1.0	–	4.6	–
23	706–707	13.2	0.7	3.9	–	1.0	2.2	2.2	–
24	710–711	8.3	0.9	0.6	–	1.0	2.1	2.2	–
25	712–713	4.8	0.7	1.6	–	1.05	1.6	4.6	–
26	714–715	10.3	0.4	0.8	–	1.1	2.1	3.4	–

* assumed

Crystallinity Scale

1. 0.00 – 0.20 = perfectly crystallized
2. 0.20 – 0.40 = very well crystallized
3. 0.40 – 0.60 = well crystallized
4. 0.60 – 0.80 = fairly well crystallized
5. 0.80 – 1.0 = poorly crystallized
6. 1 – or more = v. poorly crystallized or un-crystallized

After Biscay (1965)

Crystallinity Measurements after Jacobs (1974)

Height Ratios			½ Peak Width / Peak Height				Crystallinity Scale* based on last column results			
K/I	**K/M**	**K/Mix**	**K**	**I**	**M**	**Mixed Layer**	**K**	**I**	**M**	**Mixed Layer**
–	–	–	0.62	–	–	–	4			
–	–	–	0.59	–	–	–	3			
–	–	–	0.33	–	–	–	2			
1.56	–	–	0.27	4.28	–		2	6		
18.29	11.64	25.60	0.11	2.14	2.63	4.00	1	6	6	6
14.0	10.77	15.56	0.10	2.30	2.31	1.67	1	6	6	6
19.80	12.38	16.50	0.13	3.00	3.13	2.17	1	6	6	6
22.50	13.50	19.29	0.10	4.00	2.50	2.14	1	6	6	6
25.00	15.00	25.00	0.19	6.33	4.20	5.00	1	6	6	6
19.60	10.89	19.60	0.14	3.00	2.89	2.80	1	6	6	6
36.00	36.00	–	0.13	5.00	8.33	–	1	6	6	–
29.67	29.67	89.00	0.15	6.00	8.67	13.00	1	6	6	6
55.00	41.25	–	0.08	5.67	6.25	–	1	6	6	–
27.50	18.33	82.5	0.08	3.83	3.33	3.00	1	6	6	6
18.50	2.85	–?	0.08	2.17	1.08	–?	1	6	6	–
12.40	15.50	–	0.11	1.60	3.88	–	1	6	6	–
17.00	17.00	9.70	0.22	5.00	7.50	2.86	2	6	6	6
26.00	15.60	39.00	0.17	6.00	6.00	6.00	1	6	6	6
30.00	20.00	22.50	0.12	5.67	5.56	5.50	1	6	6	6
27.50	27.50	?	0.10	5.00	8.00	?	1	6	6	–
–	–	–	0.15	–	–	–	1	6	6	–
–	6.43	–	0.11	–	3.29	–	1	–	6	–
18.86	3.38	–	0.08	3.14	0.56	–	1	6	3	–
9.22	13.83	–	0.12	2.33	3.67	–	1	6	6	–
6.86	3.00	–	0.22	2.29	2.88	–	2	6	6	–
25.75	12.88	–	0.11	5.25	4.25	–	1	6	6	–

Table 4. Summarized quantitative estimates. (based on peak height) of clay minerals present in Buwaib-Biyad Wasia Formations, at outcrop.

Series No.	Location & Sample No.	Kaolinite Peak		Illite Peak		Montmorillonite Peak		Height Ratios		½ Peak Width / Peak Height			Crystal.ø Scale			Remarks*
		Height	Width	H	W	H	W	K / I	K / M	K	I	M	K	I	M	
1	5	11.70	0.90	1.50	2.40	0.80	1.60	7.80	14.63	0.08	1.60	2.00	1	6	6	A
2	12a	12.00	0.95	1.10	2.70	2.10	8.50	10.91	5.71	0.08	2.45	4.05	1	6	6	
3	3W	3.00	1.30	1.40	1.40	?	?	2.14	?	0.43	1.00	?	3	6	?	
4	2W	2.80	1.80	0.80	2.90	–	–	3.50	–	0.64	3.63	–	4	6	–	B
5	1W	3.30	1.50	1.20	1.10	?	?	2.75	?	0.45	0.92	?	3	5	?	
6	9Wa	8.10	0.95	–	–	–	–	–	–	0.12	–	–	1	–	–	C
7	24H	12.20	1.10	1.10	1.80	–	–	11.09	–	0.09	1.64	–	1	6	–	D
8	13H	5.00	0.80	0.60	0.80	–	–	8.33	–	0.16	1.33	–	1	6	–	
9	13aB	8.70	1.10	–	–	2.10	5.60	–	4.14	0.13	–	2.67	1	–	6	E
10	B1	6.40	0.75	0.50	1.60	0.80	1.80	12.80	8.00	0.12	3.20	2.25	1	6	6	F
11	B2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	19C	–	–	–	–	–	–	–	1	–	–	–	–	–	–	
13	17C	0.60	0.80	–	–	–	–	–	–	–	–	–	–	–	–	
14	15C	0.65	0.80	–	–	–	–	–	–	–	–	–	–	–	–	
15	10C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
16	9C	11.40	0.70	0.70	0.80	0.75	1.10	16.29	15.20	0.06	1.14	1.47	1	6	6	G
17	6C	2.20	0.70	–	–	–	–	–	–	–	–	–	–	–	–	
18	4C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
19	1C	3.50	0.65	0.65	1.50	–	–	5.38	–	0.19	2.31	–	1	6	–	

ø See Crystallinity Scale in Table 3

* Sample are selected from:

A – Biyad SS. at y-y' section, South Wadi as Sahba.

B – Locality 2; Jabal Mughayran (Biyad).

C – Wasia SS, Section at Locality 12, Khashm Al-Khanasir.

D – Locality 6, Khashm Al-Halal.

E – Locality 10, Khashm Al-Buwaybiyat.

F – Buwaib Ls. at y-y section: South Wadi as Sahba.

G – Buwaib Ls. Section at Locality 11, Khashm Ath-Thamama.

معرفة بيئات ترسيب صخور البويب ، البياض ، والوسيع بواسطة تحليل انكسارات أشعة اكس

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حللت عدة عينات من الصلصال والطين الصفحي التحت سطحية (من بئر PW_3) والسطحية لمتكونات البويب ، البياض ، والوسيع الظاهرة في أواسط المملكة العربية السعودية وذلك أولا لتعيين أنواع المعادن الطينية وغير الطينية وثانيا للتعرف على احتمالات بيئاتهم الترسيبية وقد بينت القمم المنكسرة لهذه العينات أن معدن الطين الكاولينيت (Kaolinite) شائع التواجد في رواسب البياض والوسيع وبشكل كامل وجيد التبلور . المعادن الطينية الأخرى التي تتبع على التوالي في الكمية هي الإليت (Illite) والمونتموريللونيت (Montmorillonite) وخليط من طبقات الطين . كثرة تواجد معدن الطين كاولينيت في رواسب البياض والوسيع تشير إلى بيئة قارية أو غير بحرية لهذه الرواسب . وقد عضد هذا بالحقيقة أن معدن الكاولينيت يوجد على شكل متبلور جيد . وجود كل من الإليت والمونتموريللونيت قد يكون له علاقة بالحالات الطبيعية والكيميائية الخاصة التي سادت أثناء عمليات الترسيب والتغييرات المتأخرة (Diagenesis) . بالإضافة إلى ذلك فإن الكميات القليلة جداً من معادن الطين المونتموريللونيت والإليت التي ظهرت في قليل من عينات البويب الكربونية (Carbonate) ربما تشير إلى تكوينه في بيئة بحرية .