Geol. Bull. Punjab Univ. Vol. 40-41, 2005-6, pp 27-44

GEOLOGY OF THE LOWER JURASSIC DATTA FORMATION, KALA CHITTA RANGE, PAKISTAN

BY

MUHAMMAD KALEEM AKHTER QURESHI
Geological Survey of Pakistan, Trade Centre Lohar Town Phase II, Lahore, Pakistan.
Email: mkaleemakhter@yahoo.com

AND

SHAHID GHAZI, AFTAB AHMAD BUTT
Institute of Geology, Quaid-e-Azam Campus, University of the Punjab, Lahore-54590, Pakistan.

Abstract: Detailed *geological mapping contributed towards the tectonic framework of the Kala Chitta Range for the purpose of a compressive knowledge of the mode of occurrence of the Fire Clay horizons in the Datta Formation .Furthermore, detailed analytical work was carried out to elucidate the mineralogy of the Fire Clays. Lithological details and the depositional style have been highlighted comparative data of the Datta Formation with the adjoining areas has also been presented.*

INTRODUCTION

The name Datta Formation was introduced by Danilchik and Shah (1967) after the Datta Nala section in the Trans Indus Salt Range, to replace the Variegated Series of Gee (1945). This name has also been extended to the Kala Chitta Range and adjoining areas by the Stratigraphic Committee of Pakistan (Fatmi 1973). In the Kala Chitta Range, the Datta Formation represents low-stand deposits formed during a complete sea level withdrawal over a gentle undulating relief provided by the unconformable surface of the Upper Triassic Kingriali Formation. Due to the economic significance of the fireclay deposits in the Datta Formation, Ashraf et al. (1976) carried out investigation on some of the isolated exposures of the fireclay horizons of the Datta Formation, while Baluch (1986) gave an account of Bauxitic clays of Nawa area.

The present investigation is based on the comprehensive knowledge of the tectonic behaviour and mode of occurrence of the fireclays in the Datta Formation throughout the Kala Chitta Range after the detailed geological mapping and systematic sampling of the properly located and well distributed lithosomes in the formation particularly in the Surge, Chak Jabbi, Sakhi Zindapir area of the Kala Chitta Range (Fig.l).

METHODOLOGY

Considering the economic importance of the fireclays in the Lower Jurassic Datta Formation, a detailed study was planned to be carried out in Surg- Chak Jabbi- Sakhi Zindapir, in the central Kala Chitta Range due to their excellent exposures and easy access.

Precisely, well located samples were taken from different well developed fireclay horizons of the Datta Formation. These horizon are mapped in detail (Fig. 2). The location of the samples, the lithological composition and the thicknesses of the various lithozones are given.

The detailed laboratory studies including geochemical analysis (Table Nos.I-2) differential thermal analysis Crable No.3) and XRD testing Crable NO'iA-5) were carried out in order to know the mineral composition of the fireclays which is largely kaolinite and diaspore, quartz being present invariably. The significant of these clays as compared with those of other areas is discussed.

Geochemical Behaviour

The geochemical analysis were carried out with the help of Scanning Electron Microscope (SEM, Table No. 1) and by wet geochemical methods Table No. 2.

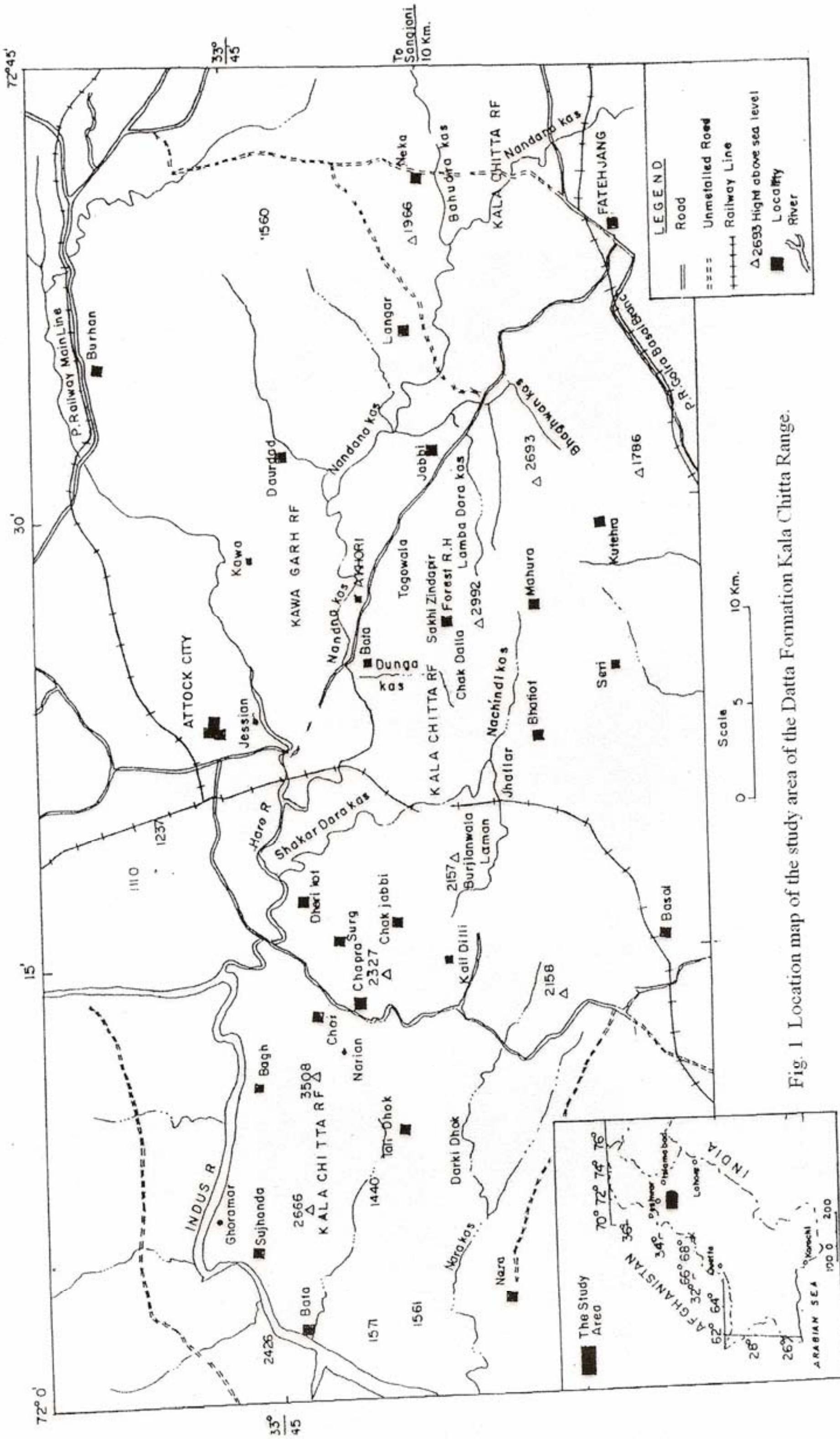


Fig. 1 Location map of the Datta Formation Kala Chitta Range.

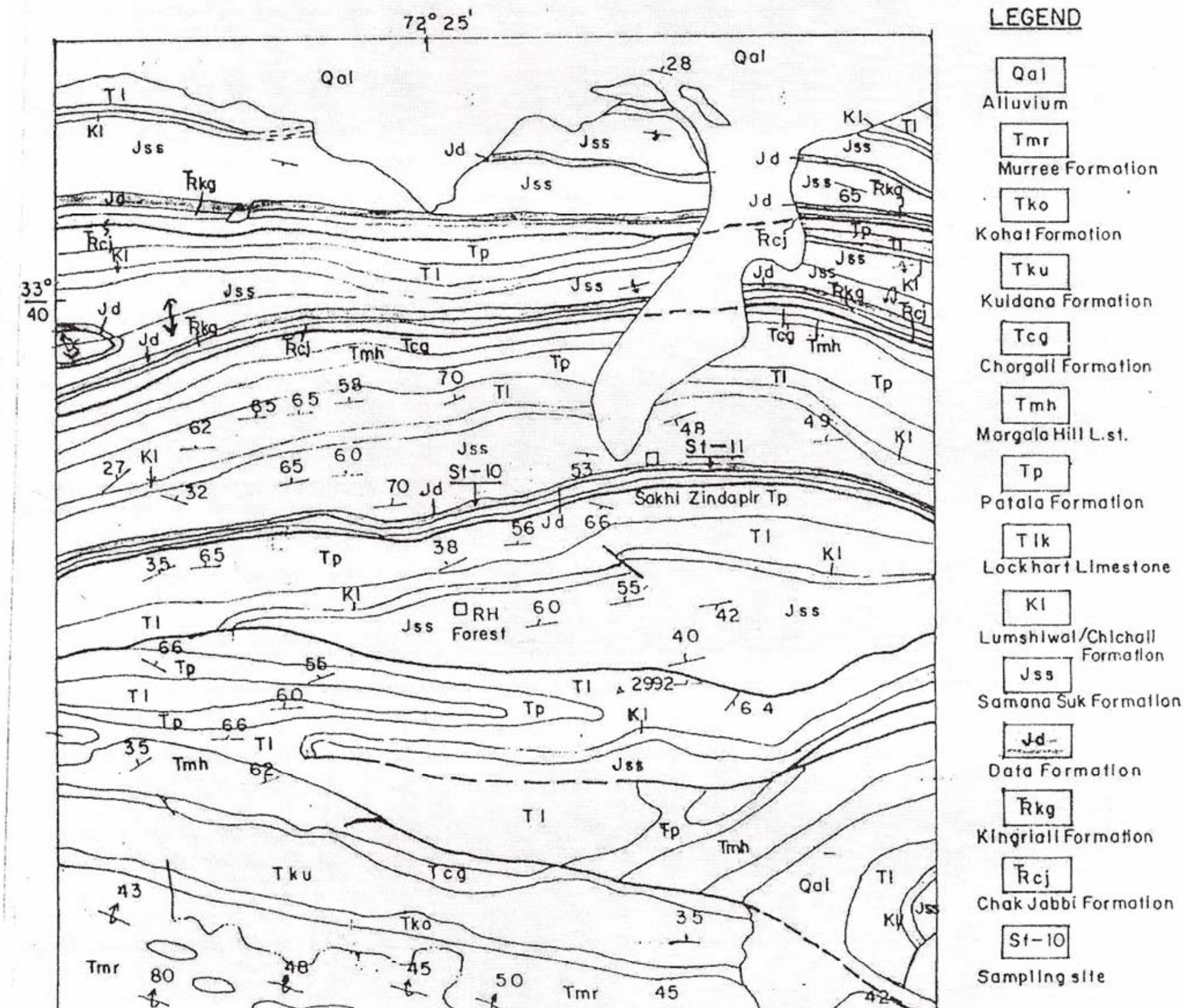


Fig . 2 Geological map of Sakhi Zindapir area showing distribution of Fireclay-bauxite bearing Datta Formation.

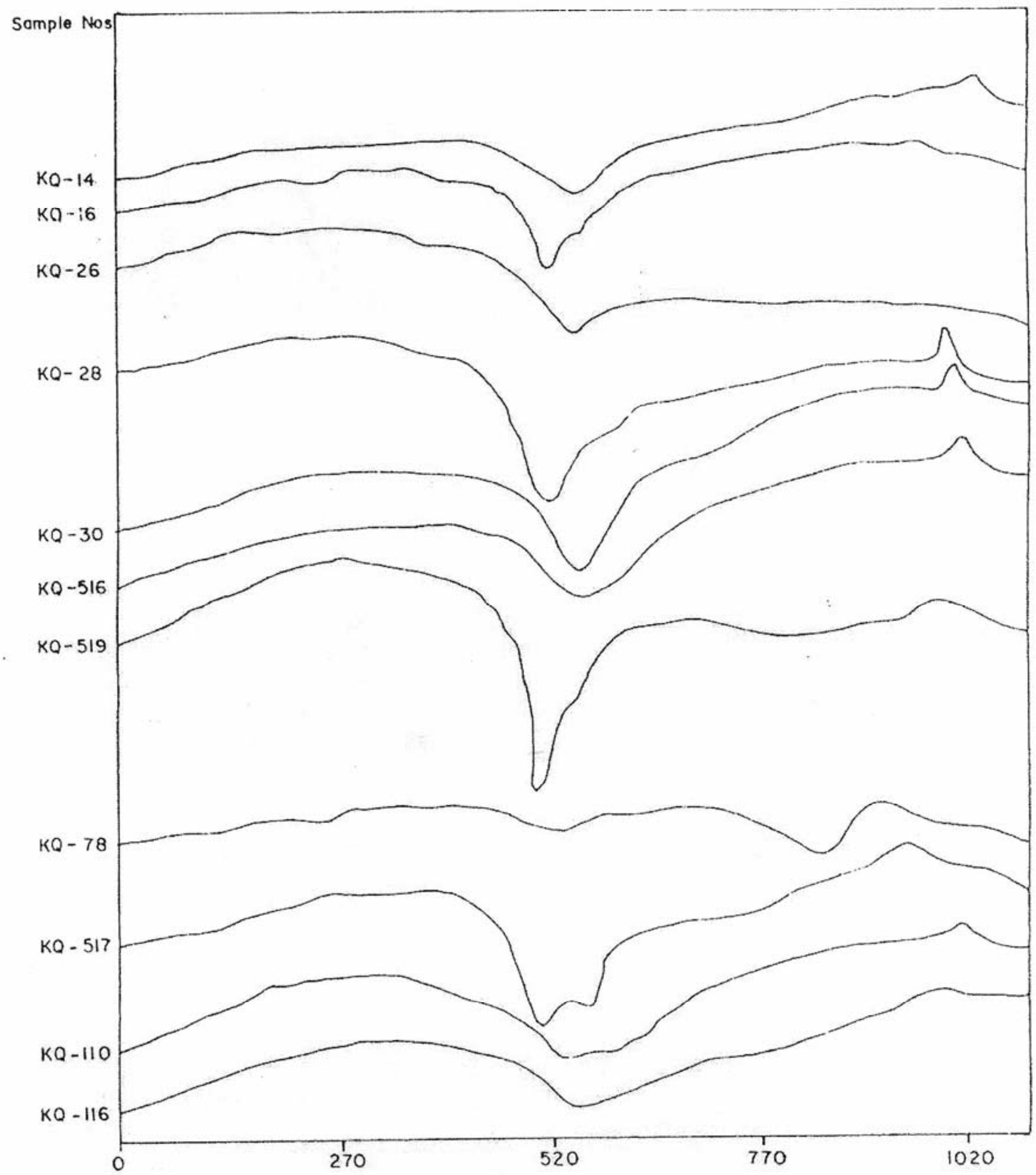


Fig. 3 DTA Curves of fireclay samples from surg-chak Jabbi-zindapir area Kala Chitta Range
(for explanation see Table No. 3)

The chemical composition of the samples show a remarkable difference in A 1203 taken from the upper part of the Datta Formation, ranging from 39 .61 % to the over 78 % (samples Nos. 15,17,78,516,517,519; Table No.2) with an overall low value at Sakhi Zindapir Section where the A 1203 does not exceed more than 26.09 % with high silica of the order of 69 .26% (samples Nos. 110.11; Table No.1). The clays from middle part show an average composition of A 1203 ranging from 36.21 % to 44.19 % (sample Nos. 16.26,28,30.517; Table No.2).

Lithology

The Datta Formation in the central and parts of the western Kala Chitta Range, comprises a complex facies of (1) clays, claystone with subordinate bauxitic lenses in the upper part and (2) quartzose sandstone, hematitic sandstone and ironstone in the lower part with (3) laterite commonly present at the base. Fireclay is present in the upper part of the Datta Formation, that comprise these lithosomes (red ironstone to hematitic sandstone, white quartzise sandstone, white to grey and purple clay and bauxite) in a lateral pinch-out relationship. Vertically, the lithosomes have distinctly gradational to abrupt relationship. The lithosomes pinch and swell rapidly, without definite trend. Isolated areas with predominance of anyone or more of the lithozones, can be identified. In the eastern Kala Chitta, the fireclay part is not present and the formation comprises only the quartzose ferruginous sandstone or sandy laterite, limiting the scope of mining activity in the area. The formation unconformably overlies the Kingraili Formation and is composed of red ferruginous or lateritized sandstone grading up into medium to fine grained white quartzose sandstone. The quartzose sandstone is overlain by white to cream clay with sand to silt sized quartz grains in the lower part. Instances of occasional quartzose sand over clay or of red sandstone with clay are not uncommon. Ironstone to ferruginous sandstone is the most common association in the subject area. In some parts the Datta Formation unconformably overlies the Chak Jabbi Limestone and the Kingriali Formation had been completely eroded due to the Upper Triassic denudation.

LITHOSTRATIGRAPHY

The following lithological units have been identified in the Datta Formation from the Kala Chitta Range.

Ironstone/laterite

It represents the basal most lithosome being usually developed over the irregular top surface of the Kingraili Formation. It dominantly consists of red ferruginous claystone with dark red, hematitic nodules (up to 7.0 cm), which are irregular to near oval shape.

Ferruginous sandstone

It consists of ill sorted medium to coarse grained red to maroon sandstone, well bedded to poorly bedded and ferruginous. At places it has hematitic intraclasts. Commonly, it overlies either the Kingraili Formation (unconformably) or the ironstone (gradationally). Rare instances of cross-stratification are also present wherein fine and coarse grained sets are repeated.

Quartzose sandstone

It is quite immature white sand, slightly calcareous in parts, medium to coarse grained and up to 6 meters thick. At places it has angular-subangular quartz grains in clay matrix. Lenses of quartzose sandstone usually overly the ferruginous sandstone. Sometimes these are found within the clay zone. It becomes more compact in the eastern most occurrences that can be used as silica sand. South of Narian Village (Fig. No. I) in the northern most strip of the Datta Formation, a basal zone of greenish grey to brownish grey, hard quartzitic sandstone that weathers to dull maroon colour is developed.

Bauxite

It is rarely found and is present in the form of irregular lenses in massive clay. At places, however, a thin blanket of bauxite is also found. Bauxite is distinguishable from clay on the basis of its hard nature, subconchoidal fracture, high specific gravity and mostly concentrically layered oolites to pisolites.

Clay

A variety of clay is found. It is white cream, yellow, light grey, pink and purple. It is mostly massive and stratification is imparted by bands of different colour or other lithologies. It is brittle, splintery, or soil like, and non-oolitic, or pisolitic. Occurrence of medium grey, slightly compact and oval intra clasts in massive white to light grey clay is quite common, which are sometime bauxitic.The fire clays occur in the form of lenses that pinch and swell rapidly. An interesting feature common to almost all the big or small lenses is that the clay occupies pouches formed in the top part of the Kingraili Formation due to the erosion subsequent to the regional, Late Triassic-Early Jurassic uplift.

CHEMICAL ANALYSIS

The chemical composition of the sample show a remarkable difference in Ah03 taken from the upper part of the Datta Formation, ranging from 39.61% to over 78% (sample Nos. 15, 17,78,516,517,519; Table

No.2) with an overall low value at Sakhi Zindapir Section where the Al203 does not exceed more than 26.09% with high silica of the order of 69.26% (sample nos. 110, 117; Table No.1). The clays form middle part show an average composition of Ah03 ranging from 36.21 % to 44.19% (sample Nos. 16,26, 28, 30, 517; Table No.2).

Table-1
Chemical analysis of Fireclay Samples from Surg-Chak Jabbi Area, Kala Chitta Range (Determined by SEM)

Sample No.	KQ-16	KQ-28	KQ-78	KQ-110	KQ-1l7	KQ-517
SiO_2	37.28	51.76	29.15	66.58	69.26	43.03
AhO_3	51.60	45.04	25.13	22.29	26.09	51.73
Fe_2O_3	5.59	0.67	7.22	8.37	0.48	0.87
CaO	0.00	0.00	34.37	0.64	0.40	0.21
MgO	0.37	0.00	1.15	0.00	0.34	0.00
Na_2O	0.95	0.68	1.11	0.00	1.01	1.34
K_2O	0.32	0.19	0.52	0.21	0.39	0.70
TiO_2	3.90	1.66	1.35	1.90	2.03	2.12
Total	100.01	99.99	100.00	99.99	100.00	100.00

The upper part of the formation shows less silica values ranging from 49% to 26.37% (very rarely high values up to 44.88% sample No. 78, Table No.2) and % age of iron ranging from 0.18% to 2.0% as compared with the lower part of the formation. Alkalies, (0.02% to 2.82%) Magnesium (0.00% to 0.75%) and Ti02 (0.20% to 3.37%) do not show any remarkable variation. The Ti02 composition ratio is directly proportionate to Fe203 and it increases or decreases along with iron. An increased value of CaO (22.64) has been found (Sample No. 77; Table No.2) in rare cases which may be due to the contamination by calcite solutions from overlying limestone beds of the Samana Suk Formation. The loss on ignition shows a similar trend (l0.30% 14.60%) in almost all samples.

Table-2: Chemical Analysis of the Fireclay Samples from Surg -Chak Jabbi- Zindapir area, Kala Chitta Range.

Sample No.	KQ-14	KQ-15	KQ-16	KQ-17	KQ-26	KQ-28	KQ-30	KQ-77	KQ-78	KQ-516	KQ-517	KQ-518	KQ-519
I/L	13.42	13.92	13.66	14.16	14.06	14.18	14.60	34.12	12.72	14.34	14.58	10.30	14.35
SiO^{2}	45.60	3.49	31.29	7.39	44.50	44.42	44.40	19.20	44.88	43.20	36.76	27.84	26.37
$Al^{2}O^{3}$	36.21	78.95	43.05	73.68	38.00	38.65	37.39	16.55	39.61	40.1 0	44.19	30.81	56.50
$Fe^{2}O^{3}$	2.30	2.00	4.83	2.50	1.00	0.57	1.52	4.75	1.10	0.84	0.74	25.02	0.18
CaO	0.14	0.22	0.00	0.21	0.35	0.00	0.32	22.64	0.14	0.29	0.18	3.21	0.25
MgO	0.03	0.05	0.32	0.10	0.19	0.00	0.44	0.75	0.05	0.40	0.00	0.23	0.35
Na_2O	0.49	0.39	0.82	0.30	0.51	0.58	0.15	0.73	0.48	0.21	1.14	0.00	0.02
K_2O	0.38	0.07	2.82	0.06	0.37	0.16	0.20	0.34	0.32	0.30	0.60	0.00	0.02
TiO_2	1.21	0.87	3.37	1.32	0.20	1.41	0.79	0.89	0.39	0.21	1.81	2.47	1.80
Total	99.78	99.96	99.96	99.72	99.18	99.97	99.81	99.95	99.69	99.89	100.00	99.88	99.84

MINERAL COMPOSITION

As the fireclays from the Datta Formation are very fine grained it is not possible to determine the mineralogical composition through ordinary polarizing microscope therefore, X-ray diffraction (XRD) analysis, and Differential Thermal Analysis (DTA) techniques were employed to determine the mineral composition of the fireclays.

a. Differential Thermal Analysis (DTA): The samples showing almost the same chemical composition were selected for DTA and XRD analysis. The DTA curves of the fireclay samples are shown in Fig. No.3 and the values are given in the table No.3. it is revealed from the DTA analysis that almost all the fireclays show the mineral composition of Kaolinite and diaspore with the exception of sample No. 78 (Table No.3) in which the Al203 is represented by gibbsite. The sample Nos. 14,28,30,516, and 519 (Fig. No.3; table No. 3) show the exothermic peaks of Kaolinite at about 988°C, whereas the sample Nos. 16,26,78 and 517 (Fig. No.3; Table No.3) show peaks at different temperature which corresponds to the variation in the alumina composition. A shift in endothermic peaks of diaspore is noted in the samples which are also due to the variation in Al_2O_3) composition.

b. **XRD Analysis** The XRD analysis also proves that the main mineralogical composition of fireclays in the investigated area is Kaolinite, diaspore and gibbsite. The results are given in table Nos. 3,5 and the relevant peaks are shown in (Fig. Nos. 4-10), The minerals identified with the help of DTA are comparable with those of XRD results. The XRD results in some cases, however, show slight difference in the peaks and in their “d” values, which is attributed to the variation in their chemical composition.

Table-3
Minerals identified by Differential Thermal Analysis of Fireclays from Surg, Chak Jabbi and Zindapir areas, Kala Chitta Range.
(Data refers to Fig. 3)

Station No.	Sample No.	Temperature	Peak	Minerals
1.	KQ-14	534°C 988°C	Endo Exo	Diaspore Kaolinite
2.	KQ-16	504°C 935°C 955°C	Endo Endo Exo	Diaspore Kaolinite
3.	KQ-26	537°C	Endo	Diaspore
4.	KQ-28	536°C 522°C 988°C	Endo Endo Exo	Diaspore Kaolinite Kaolinite
5.	KQ-30	539°C 987°C	Endo Exo	Diaspore Kaolinite
6.	KQ-516	545°C 989°C	Endo Exo	Diaspore Kaolinite
7.	KQ-519	510°C 533°C 988°C	Endo Endo Exo	Diaspore Kaolinite
8.	KQ-78	260°C 522°C 822°C	Endo Endo Exo	Gibbsite Kaolinite Calcite
9.	KQ-517	504°C 550°C 950°C	Endo Endo Exo	Kaolinite Diaspore Kaolinite
10.	KQ-IlO	522°C 550°C 992°C	Endo Endo Exo	Kaolinite Diaspore Kaolinite
11.	KQ-117	537°C 989°C	Endo Exo	Diaspore Kaolinite

Table-4
Minerals identified by X-ray diffraction data of fireclay from Surg, Chak Jabbi, and Zindapir areas, Kala Chitta Range. (Analysis carried out at PCSIR Laboratories, Lahore)

Sample No.	Minerals identified
KQ-14	Kaolinite, Quartz
KQ-16	Kaolinite, Diaspore
KQ-26	Kaolinite, Quartz
KQ-28	Kaolinite, Quartz
KQ-519	Kaolinite, Diaspore
KQ-IlO	Kaolinite, Quartz
KQ-117	Kaolinite, Quartz

Table-5
Minerals identified by X-ray diffraction data of Fireclays from Surg, Chak Jabbi, and Zindapir areas, Kala Chitta Range. (Analysis carried out at Geosciences Laboratories, GSP, Islamabad)

Sample No.	Minerals identified
KQ-77	Hematite, Geothite, Quartz, Kaolinite
KQ-78	Quartz, Kaolinite, Calcite, Gibbsite
KQ-I06	Quartz, Kaolinite, Haematite, Maghemite, Muscovite
KQ-117	Haematite, Geothite, Quartz, Kaolinite, Calcite
KQ-515	Haematite, Geothite
KQ-516	Kaolinite, Quartz
KQ-517	Kaolinite, Quartz
KQ-518	Kaolinite, Quartz

COMPARISON WITH OTHER AREAS

Salt Range: In the western Salt Range (Nammal Gorge section) the formation is of continental origin and consists of variegated sandstone and shale with carbonaceous, ferruginous, glass sand, and fireclay horizons. The fireclay is present in the lower part. Fatmi et al. (1987) described an onlap relationship of the Datta Formation over the Triassic from the western Salt Range (Lalumi-Chidru section).

Whitney et al. (1990) reported the predominance of boehmite and gibbsite in the samples from the Salt Range. On the other hand kaolinite and diaspore are the dominant minerals in the Kala Chitta Range. The iron rich laterites comprise foliated hematite (particularly in the Sakhi Zindapir) in the Kala Chitta Range with respect to the reported massive goethite in the Salt Range.

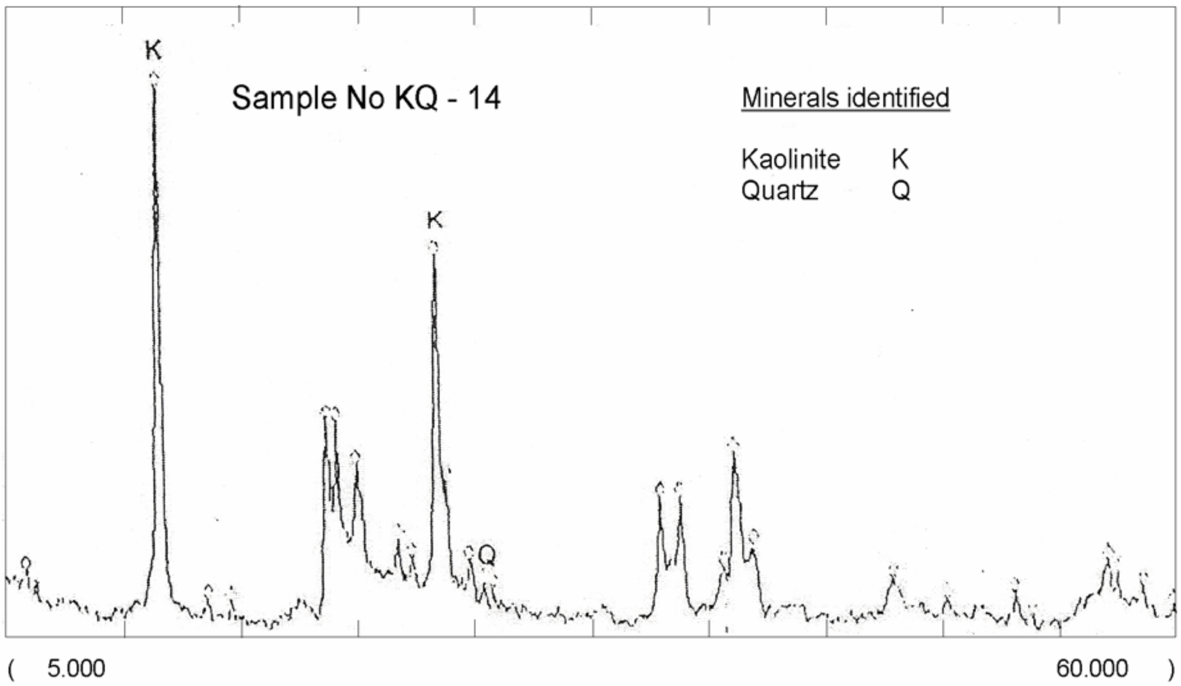
According to Veletone (1972), the thermal alteration of fireclays and bauxite causes gibbsite and boehmite to react to diaspore. The reaction of gibbsite to boehmite occurs near 120°C and the reaction of boehmite to diaspore normally occurs between 200°C - 300°C. Furthermore, the transition from goethite to hematite occurs at near 100°C.

All these reactions are too complex to use as simple or precise geothermometers. However, the presence of high temperature minerals i.e. diaspore and micaceous hematite in the Kala Chitta Range is a clear evidence of burial metamorphism in the laterite and fire clays deposits when compared to the equivalent rocks (e.g. Jurassic Datta Fire Clays in the Salt Range) having low temperature minerals such as gibbsite, boehmite and goethite. The dynamic metamorphism caused by the extensive tectonism in the Kala Chitta Range can also be responsible for this mineralogical change.

Trans Indus Ranges: Mensink et al. (1991) have described Lower Jurassic facies from localities in the Trans-Indus Range (Lat 32° 55’ Long. 71° 10’). The Datta Formation in these areas comprises cross bedded sandstone, siltstone, sandy marls and clays with mud cracks, skolithos burrows horizons, drifted wood and paleosols. A transitional change from the dolomite facies (the Kingriali Formation) to the sandstone facies (the Datta Formation) is reported. Thus, the succession from the Kingriali Formation to the Datta Formation does not appear to be separated by a discontinuity. Although the bedding planes are locally covered with Fe-crusts but their primary Jurassic origin is considered to be doubtful.

Table-6
Lithological section of the Datta Formation from Bara Oater Area Hazara (Chaudhry et al. 1994)

Bed	Facies	Environment of Deposition
I	Arenaceous dolomite with streaks and layers of grit.	Low to moderate energy marine, with worm tacks. Shallow intertidal/tidal mud flat.
II	Mudstone.	Marine, very low energy.
III	Fine to very fine grained, carbonate and quartz cemented quartz arenite.	Marine, very low energy.
IV	Very fine grained arenaceous limestone.	Marine, low energy.
V	Fine grained, quartz and carbonate cemented quartz arenite.	Marine, very low energy.
VI	Coarse grained carbonate cemented quartz arenite.	Marine, high energy.
VII	Medium grained, ferruginous quartz arenite.	Marine, low to medium energy.
VIII	Alternation bands of carbonate cemented quartz arenite and oolitic, pellectoidal limestone.	Marine, high energy.
IX	Medium to fine grained quartz and kaolinite-illite cemented quartz arenite.	Marine, bimidal, lag sand deposit.
X	Fine grained glauconitic sandstone.	Low rate of sedimentation, low energy, reducing condition, marine transgression.
XI	Medium grained quartz cemented quartz arenite.	Medium energy continental environment.



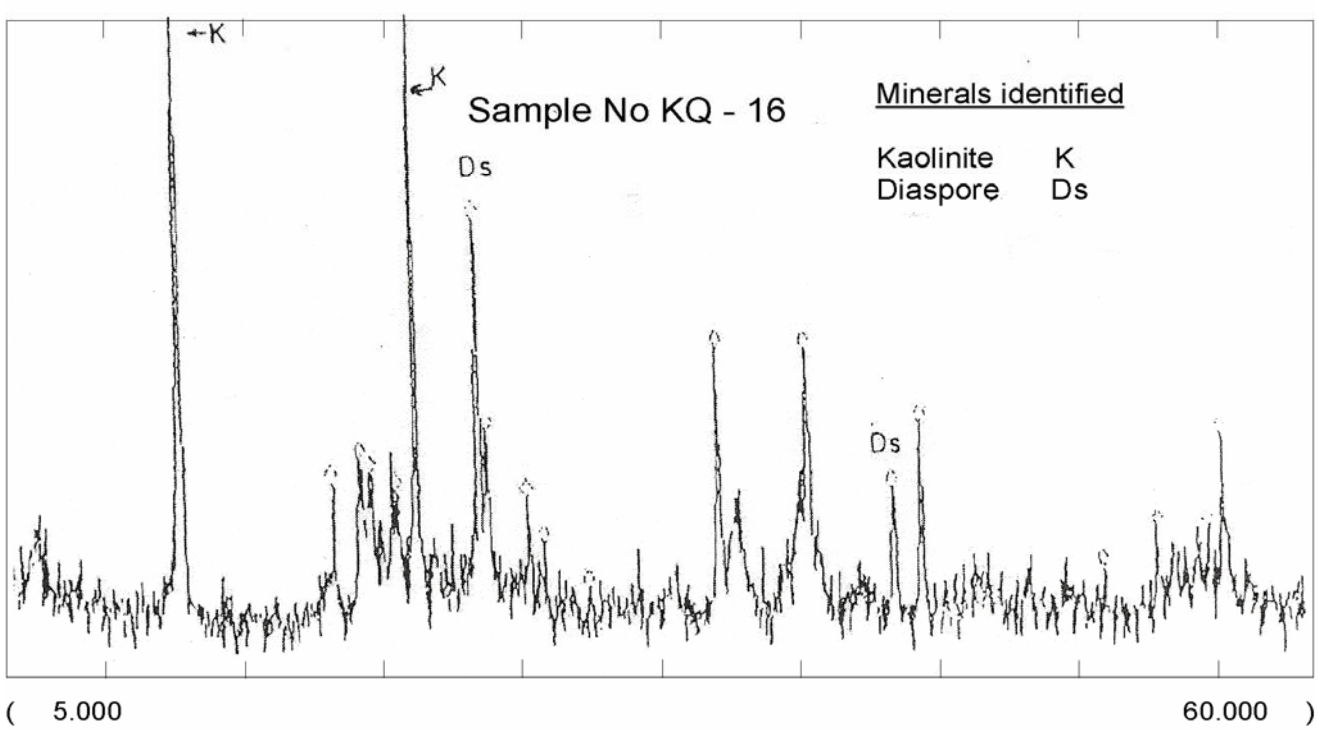
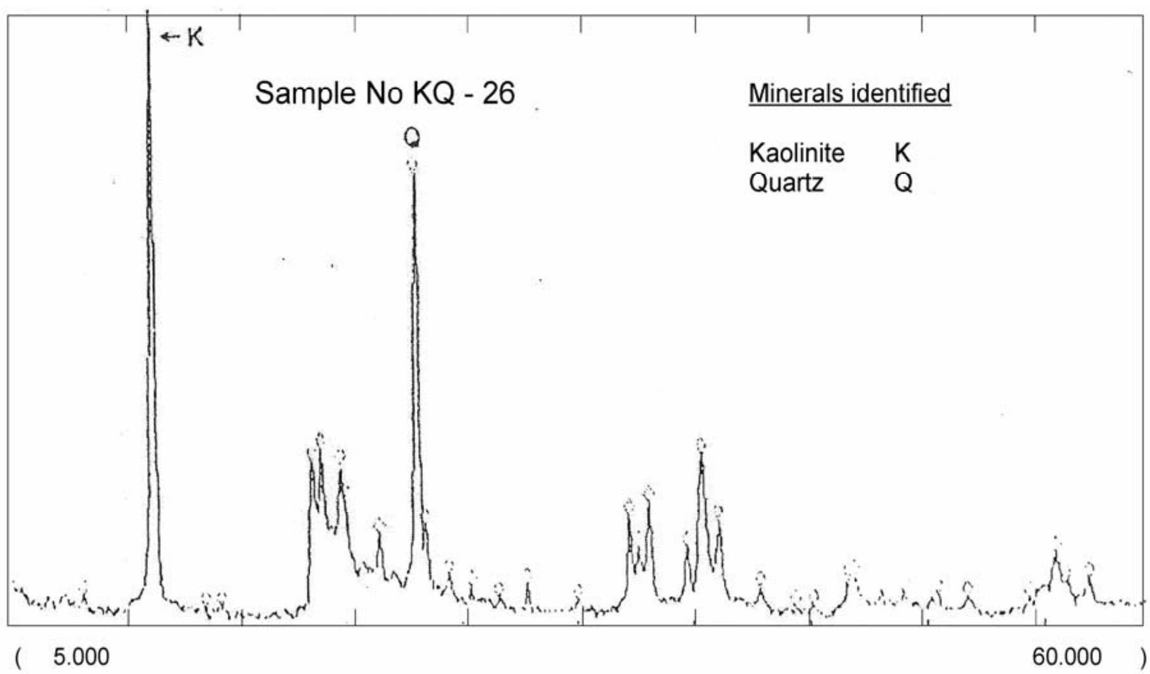


Fig 4 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-14. KQ-16) Kala Chitta Range



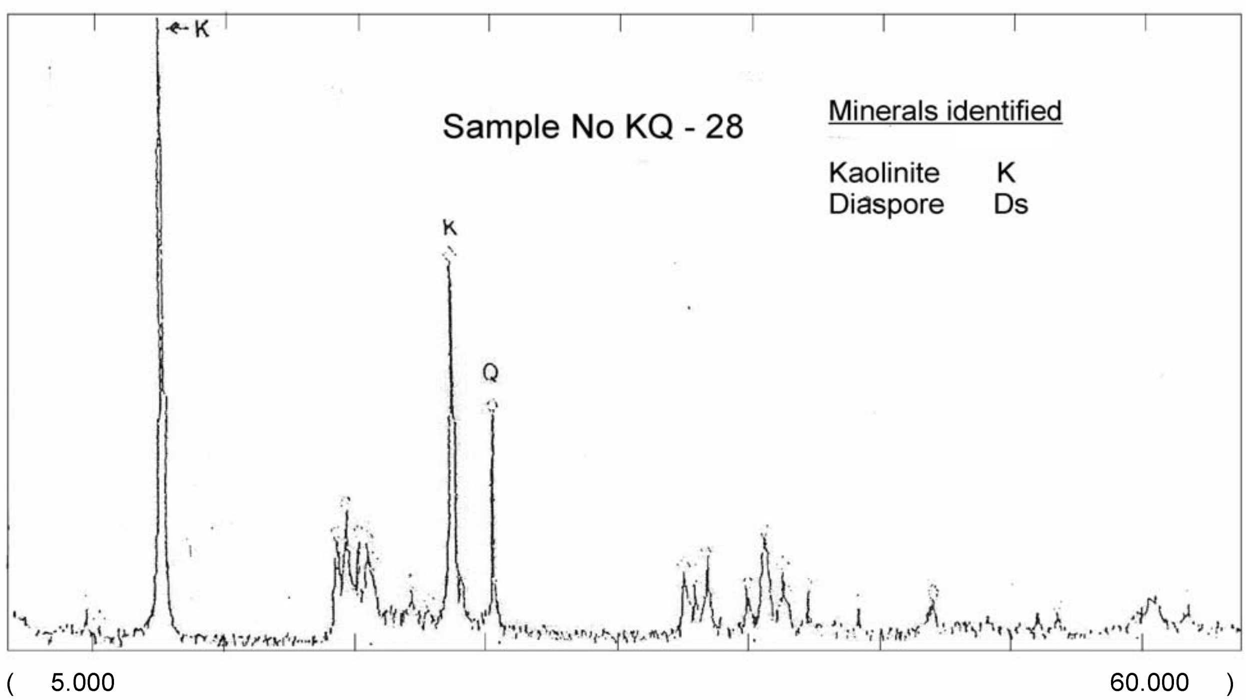


Fig 5 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-26. KQ-28) Kala Chitta Range

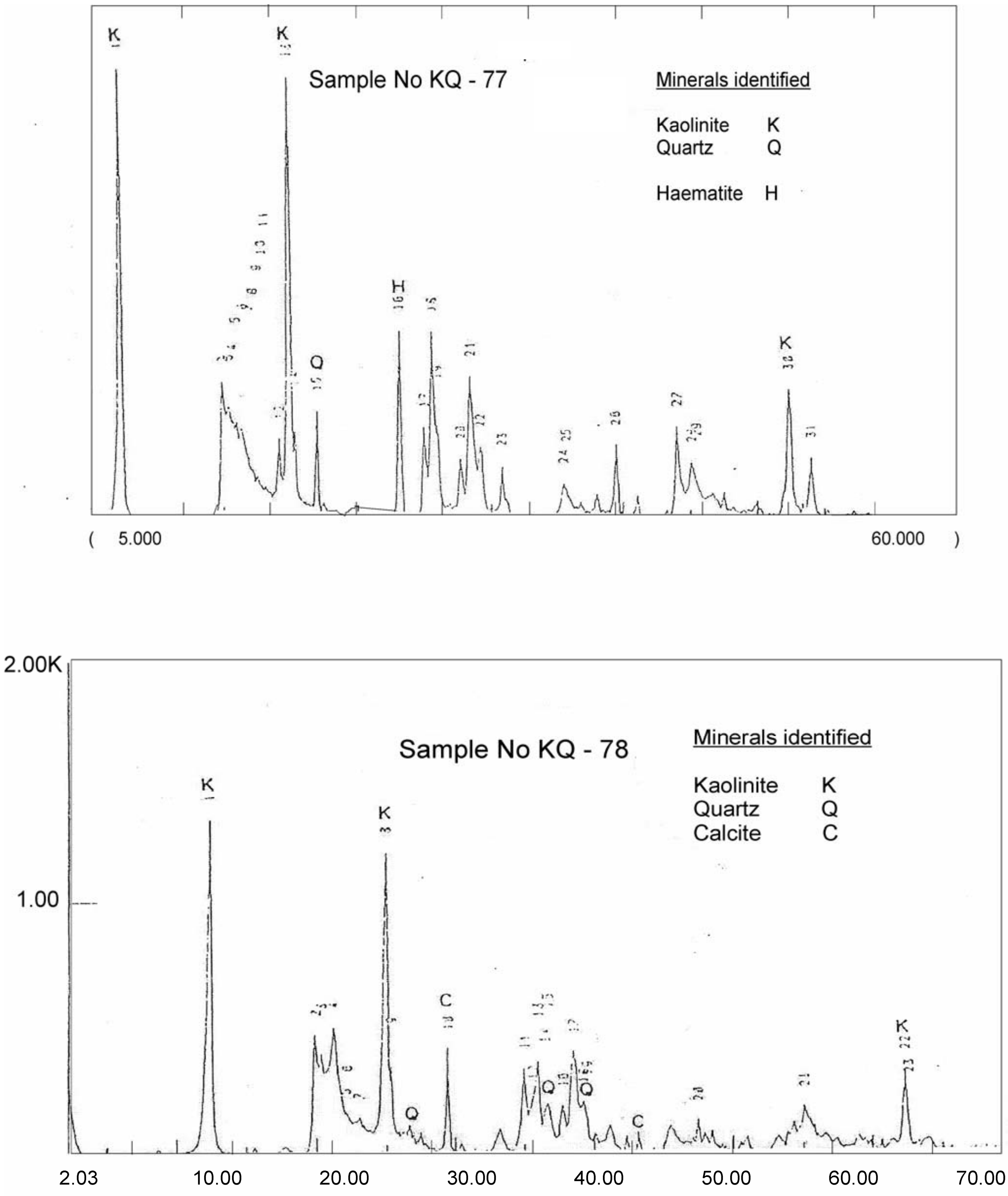


Fig 6 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-77. KQ-78) Kala Chitta Range

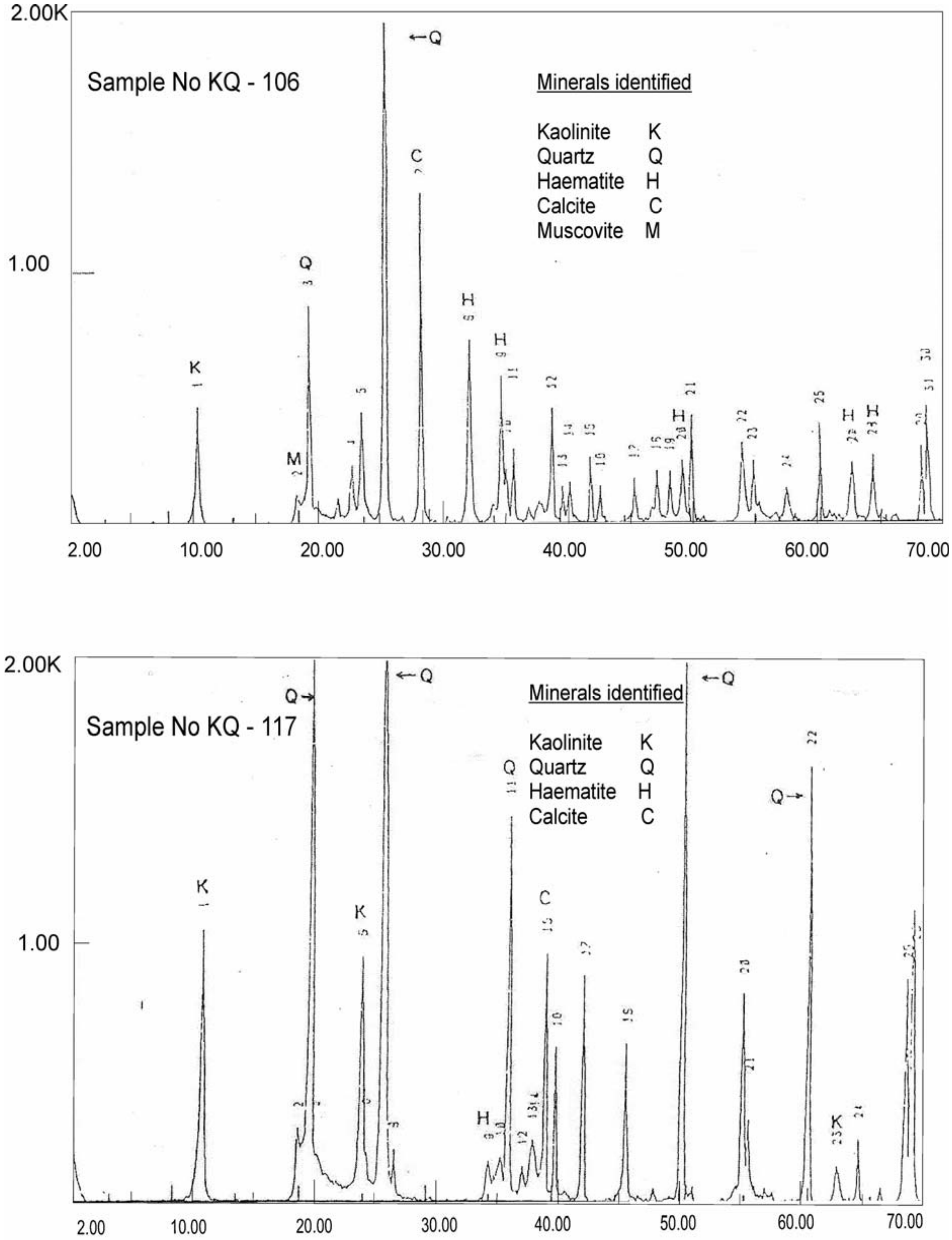
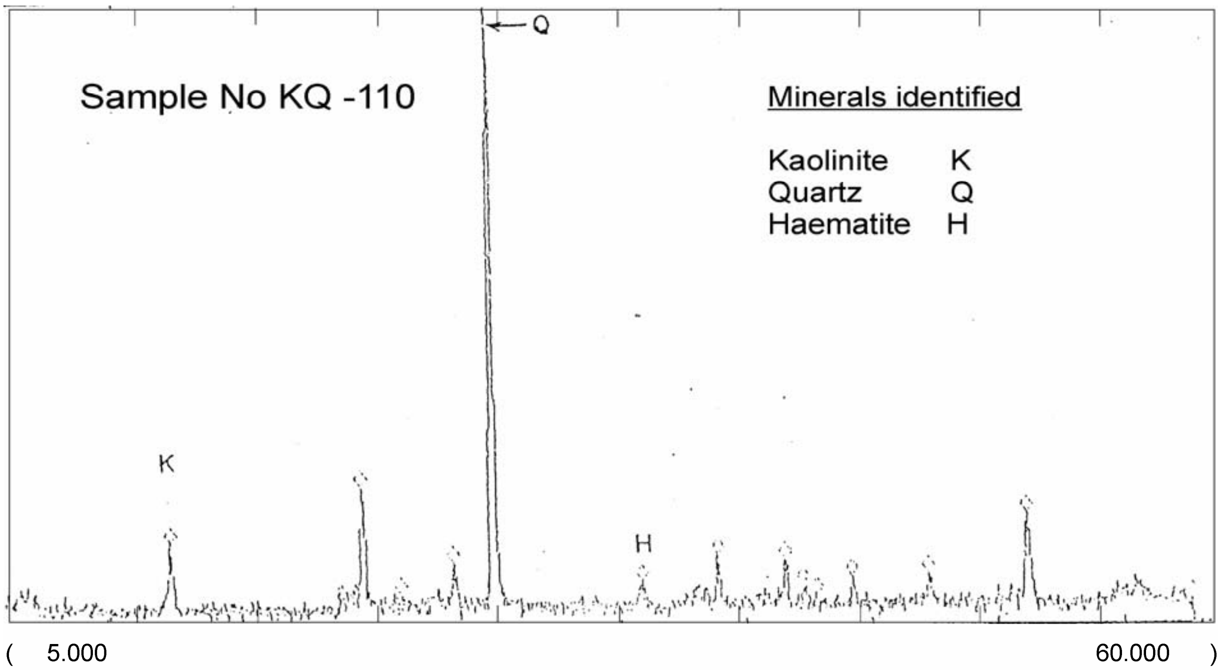


Fig 7 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-106. KQ-117) Kala Chitta Range



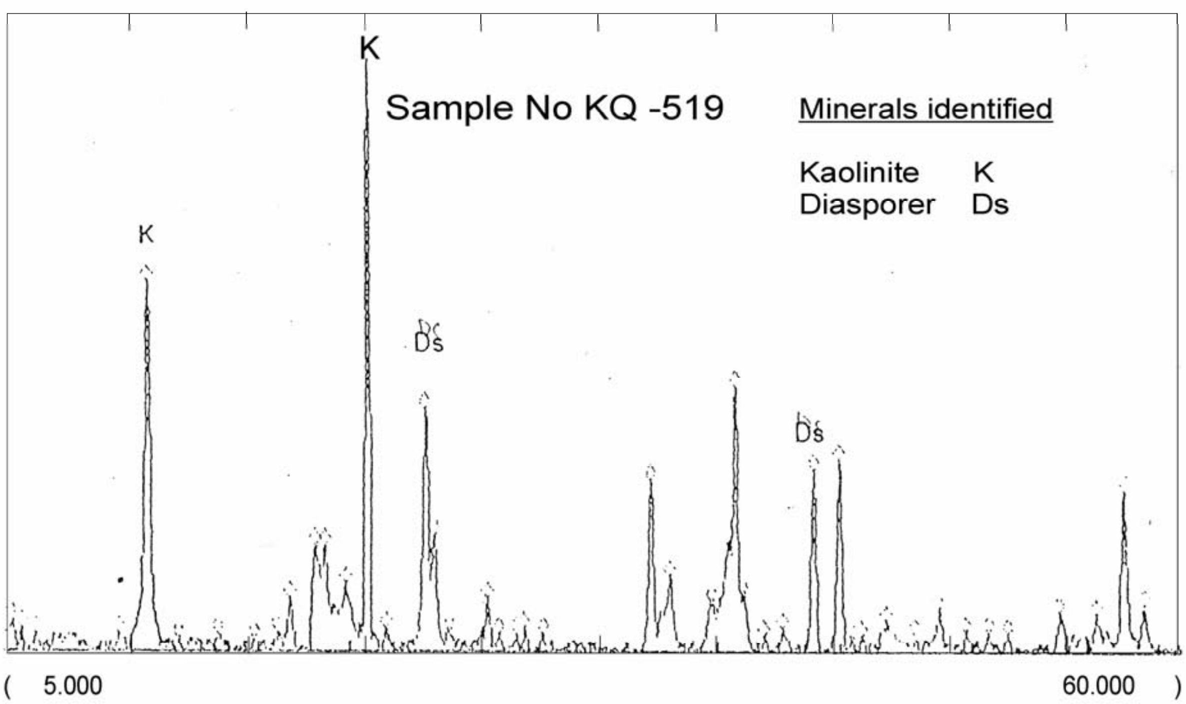


Fig 8 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-110. KQ-519) Kala Chitta Range

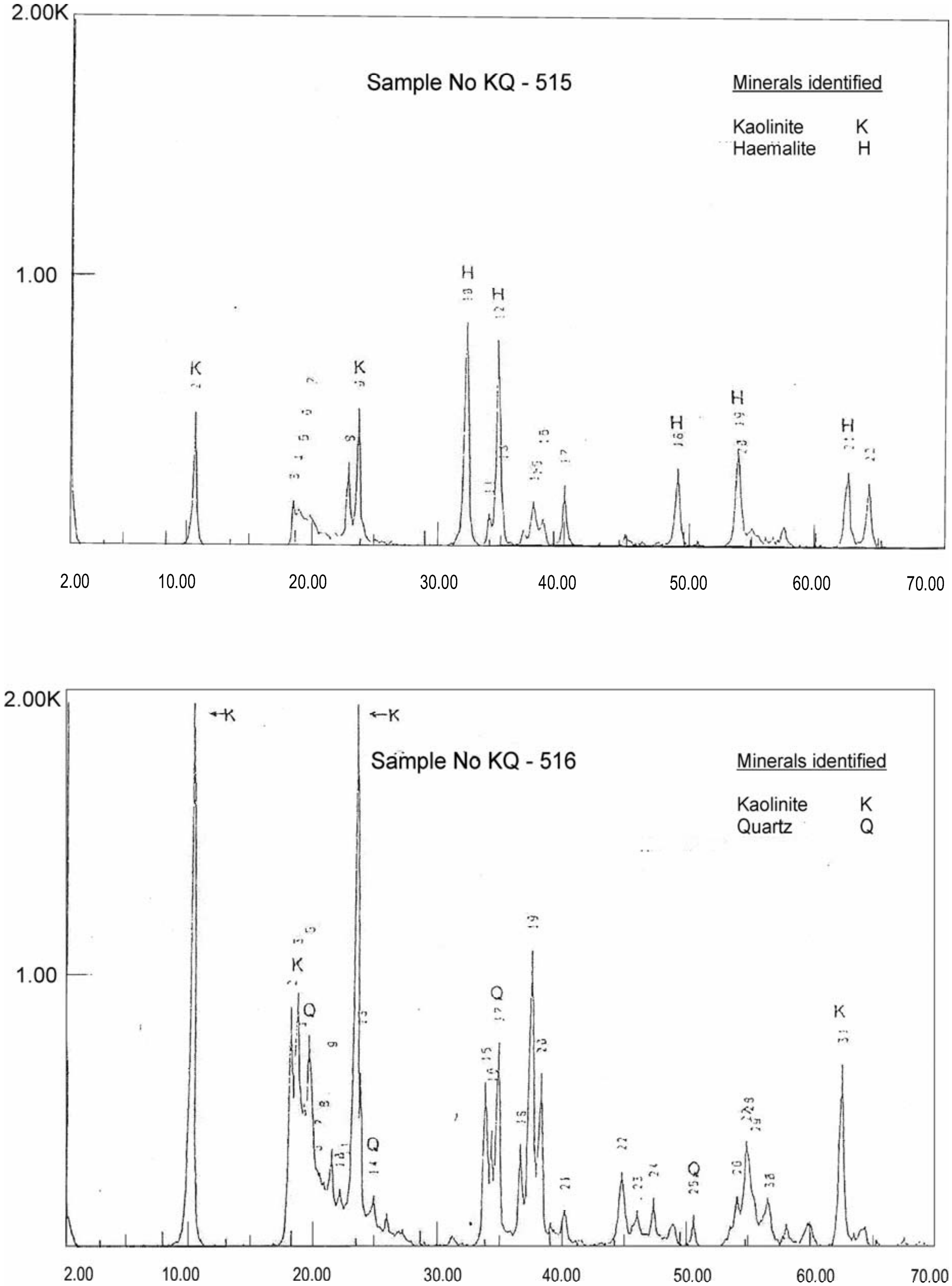


Fig 9 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-515. KQ-516) Kala Chitta Range

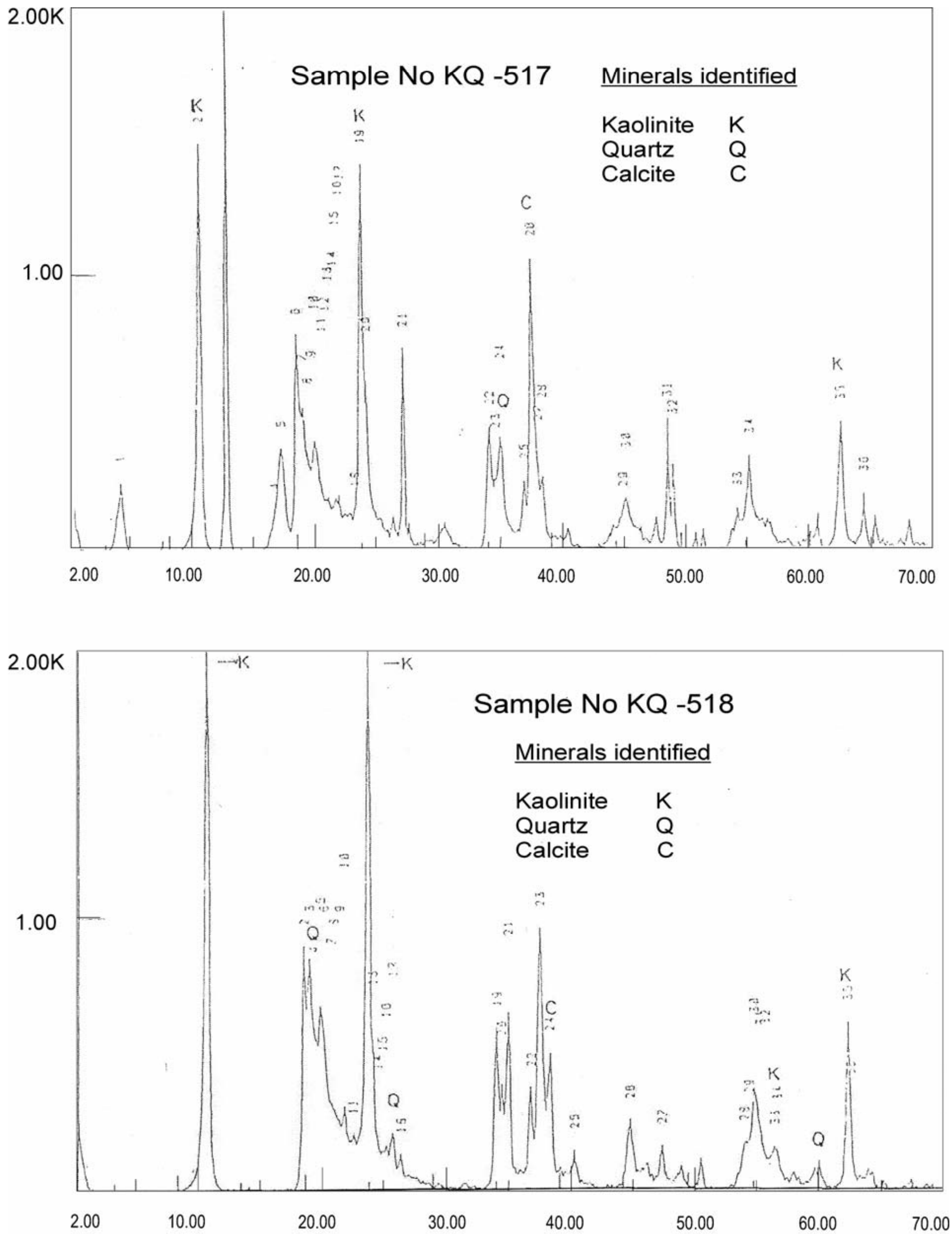


Fig 10 X-ray diffraction analyses of clays of the Datta Formation (sample no KQ-517. KQ-518) Kala Chitta Range

Kohat: Fatmi et al. (1990) described a section of the Datta Formation and the Shinawari Formation from the Shinawari type locality and adjoining areas in the Kohat region. A marked change in the facies of the Datta Formation has been observed as compared with those of the Kala Chitta Range. The formation is reported to be composed of quartzose, dolomitic, and oolitic limestone suggesting a shallow marine shoreline with development of superatidal flat.

Hazara: Chaudhry et al. (1994) measured and described the Datta Formation from the Bara-Oater area, District Abbotabad, Hazara (latitude 34° 08’ 36” E, longitude 74° 20’ 44” N). The descriptions are given in Table 6. Only the bed No. XI is comparable in lithology with the Datta Formation in the Kala Chitta Range. It appears from the descriptions of Fatmi et al. (1990) and Chaudhry et al. (1994) from Kohat and Hazara respectively, that shallow marine environmental conditions prevailed in those areas during the time of deposition of the Datta Formation, whereas in the Kala chitta Range, the Salt Range and the Trans Indus Ranges, continental deposits were laid down and the Early Jurassic transgression did not reach into these areas.

DISCUSSION

In the western Salt Range (Nammal Gorge section) the formation is of continental origin and consists of variegated sandstone and shale with carbonaceous, ferruginous, glass sand and fireclay horizons. The fireclay is present in the lower part. Fatmi et at. (1987) described an onlap relationship of the Datta Formation over the Triassic from western Salt Range (Lalumi-Chidru Section).

Whitney et at. (1990) reported the predominance of boehmite and gibbsite in the samples from the Salt Range. On the other hand, kaolinite and diaspore are the dominant minerals in the Kala Chitta Range. The iron rich laterites comprise foliated hematite (particularly in the Sakhi Zindapir) in the Kala Chitta Range with respect to the reported massive pethite in the Salt Range.

According to Veletone (1972), the thermal alteration of the fireclay and bauxite causes gibbsite and boehmite to react to diaspore. The reaction of gibbsite to boehmite occurs near 120°C and the reaction of boehmite to diaspore normally occurs between 200°C-300°C. Furthermore, the transition from goethite to hematite occurs at near 100^{o}C.

All these reactions are too complex to use as simple or precise geothermometers. However, the presence of high temperature minerals such as the diaspore and the micaceous hematite in the Kala Chitta Range is a clear evidence of burial metamorphism in the laterite and fireclays deposits when compared to the equivalent rocks (e.g. Jurassic Datta Fire Clays in the Salt Range) having low temperature minerals such as gibbsite, boehmite and goethite. The dynamic metamorphism caused by the extensive tectonism in the Kala Chitta Range can also be responsible for this mineralogical change.

Mensink et al. (1991) have described Lower Jurassic facies from localities in the Trans-Indus Range (Lat.32°55' Long.7l010'). The Datta Formation in these areas comprises cross bedded sandstone, siltstone, sandy marls and clays with mud cracks, Skolithos burrows horizons, drifted wood and paleosols. A transitional change from the dolomitic facies (the Kingriali Formation) to sandstone facies (the Datta Formation) is reported. Thus, the succession from the Kingriali Formation to the Datta Formation does not appear to be separated by a discontinuity. Although the bedding planes are locally covered with Fe-crusts but their primary Jurassic origin is considered to be doubtful.

Fatmi et al. (1990) described a section of the Datta and Shinawari Formtion from the Shinawari type locality and adjoining areas in the Kohat region (Toposheet No. 38 K). A marked change in the facies of the Datta Formtion has been observed as compared with that of the Kala Chitta Range. The formation is reported to be composed of quartzose, dolomitic and oolitic limestone suggesting a shallow marine shoreline with development of superatidal flat. Chaudhry et at. (I994) measured and described the Datta Formation from Bara Oater area District Abbotabad, Hazara (latitude 34°08'06" E, longitude 73°20'44" N). The descriptions are given in Table No. 6.

Only the bed No. XI is comparable in lithology with the Datta Formation in the Kala Chitta Range. It appears from the descriptions of Fatmi et al. (1990) and Chaudhry et at. (1994) from Kohat and Hazara, respectively, that shallow marine environmental conditions prelvailed in those areas during the time of deposition of the Datta Formation, whereas in the Kala Chitta Range, Salt Range and the Trans Indus Ranges continental deposits were laid down and the Early Jurassic transgression did not reach into these areas.

ENVIRONMENTAL INTERPRETATION

The lithological assemblage and mode of occurrence of the laterite, sandstone and fireclay of the Datta Formation suggest that these deposits were formed by the weathering of alumina rich rocks in the provenance under favourable conditions and later were transported to the present site of deposition. The conditions that favour the formation of such deposits have been studied by Dorokhin et at. (I969) and Valeton (1981) from different parts of the world and are summarized as under:

1. Presence of rocks with readily soluble minerals whose insoluble residue was rich in alumina.
2. A tropical climate with abundant rainfall alternating with dry periods.
3. High rock porosity
4. A flat or gently undulating relief.
5. Prolonged periods of rest in the earth's development in a given region.
6. Presence of bacterial or vegetable life.

It is quite likely that the conditions outlined above were approaching the ideal ones in the provenance, where the subaerial weathering of the Pre-Cambrian quartzite, rhyolite, andesite, ash, tuff and low grade metamorphics of Indian Shield - the provenance (presently exposed around Sarghoda) produced laterites and aluminous clay/bauxites, which were reworked and deposited during Early Jurassic times, in the low lying Kala Chitta area (Ashraf et aI., 1976).

Localizing effect of the irregularities of the top of Kingraili Formation is responsible for restriction of clay in the pouches and deposition of sand along the crest of protrusion. Various stages of formation of these deposits from the bed rock and transportation to the present site are given below:

1. In the first stage the weathering and alteration of bed rock in the provenance produced clays with free silica. The most of the iron, calcium, magnesium and other elements were removed.

2. The alumino-silicates were dissolved by weathering to form a aluminium hydroxide and iron hydroxide in the tropical to subtropical humid environments.

3. Favourable chemical and physical conditions also led to desilication or bauxitisation of the clay, at a certain stage. This desilication/ bauxitisation might have taken place in colloidal state around numerous favourable centers or nuclei. As silica leached out, alumina concentrated around these nuclei in the form of pisolites and nodules forming patches/lenses of bauxite depending upon the intensity of bauxitisation around these nuclei.

4. The deposition of kaolinite and bauxite occurred in definite and distinct zones. However, it is postulated that the weathering conditions have been subordinately persisting and repeatedly quick change from dry to humid conditions prevailed. These climatic fluctuations muddled up the sediments, resulting in mixing up of kaolinite and bauxite.

5. The laterite was formed on top during more tropical conditions, when iron bearing solutions were brought up from weathering bed rock by capillary action and ironstone was deposited on top of cIaylbauxite. The iron bearing solution during their upward journey impregnated the clays giving rise to lateritized clays/bauxite. The occurrence of irregular patches of ferruginous material indicates that in the provenance the lateritisation process was not regular. It might be due to the source rock being richer in aluminium than iron.

6. The rocks thus formed were transported to their present site over lateritized and weathered surface of the Kingriali Formation during the lower Jurassic with ironstone being eroded and redeposited first, forming the base of the Datta Formation.

FAUNA AND AGE

The formation is unfossiliferous in the Kala Chitta Range. However, as it underlies the *Bouleiceras* bearing beds (Fatmi, 1977) an Early Jurassic age has been assigned to the formation. In the Salt Range, Jain and Shah (1968) and Masood and Bhutta. (1985) reported a rich variety of palynomorphs belonging to the Early Jurassic age.

CONCLUSIONS

- Detailed geological mapping and the sampling of the Datta Formation have led to establish the mode of occurrence of economically important Fire Clay horizons.

- The analytical data has contributed towards determining the mineralogy of the Fire Clay horizons.

- Lithological details have highlighted the depositional pattern of the Datta Formation in comparison to its environmental style in the type area of the Salt Range as well as the Hazara Mountains.

REFERENCES

Ashraf, M., Ahmad and Faruqi, F.A 1976 Jurassic Bauxite and Kaolinite Deposits of Chhoi Area Kala Chitta Range, Pakistan, *Geol. Bull. Punjab Univ.* **12**, 41-54.

Baluch I H *(*1986) A mineralogical study of the industrial utilization of bauxitic clays of Nawa area, Kala Chitta Range, Attock District, Pakistan. *Acta Minerologica Pakistanica* **2**, 144-152.

Chaudhary, M.N., Chauhan, F.A and Ghazanfar, M. 1994 Microfacies, diagenesis, Environments of deposition and burial history of the Datta Formation from Bara Oter, District Abbottabad . *Kashmir Jour. Geol.* **11-12,** 43-58.

Danilchik, W., Shah, S.M.I., 1967 Stratigraphic nomenclature of formations in TransIndus Mountains Mianwali District, West Pakistan, *US. Geol. Surv., Project Report* (IR)PK-**33**, 1-45.

Dorokhin, Aruzhinin, Sobolevsky and Gorbunov. 1969 Economic Mineral Deposit: *Higher School Bogacheva Publication. House Moscow,* 1-368*.*

Fatmi, A. N. 1973 Lithostratigraphic units of Kohat-Potwar Province, Indus Basin, Pakistan, *Mem Geol. Surv: Pakistan.* **10**, 1-80.

Fatmi, AN., Haydri,I. Anwer, M. 1987 Disappearance and reappearance of some Mesozoic units in Lalumi Section Western Salt Range-A Stratigraphic Riddle. *Acta Mineralogica Pakistanica* **2**, 53-59.

Fatmi, AN., Anwer, M. Hussain,I. 1990 Stratigraphy of Shinawari and Datta Formations(Westren Samana Range), Kohat District, Pakistan. *Geol Bull. Punjab Univ.* **25**, 47-55.

Gee, E.R., 1945 Age of the Saline Series of Punjab and Kohat: India. *Nat. Acad. Sc. Proc*., Sec. B.**14 (6)**, 269-310.

Jain, K.P. and Shah S.C.D. 1968 Lower Jurassic Miospore assemblage from the variegated shale, Nammal Gorge, Salt Range. *Paleobot.*, **17**, 127-136.

Masood K.R. and Bhutta, AA 1985 On some new Early Jurassic Miospores from Datta Formation, Western Salt Range, Pakistan. *Kashmir Jour. Geol.* **3**, 37-58.

Mensink, H., Mertmann, D., Ahmad, S. and Shams, F. A 1985 a microfacies reconnaissance of the Kingriali Formation of the Nummal Gorge and Gula Khel Areas, *Geol. Bull. Punjab.Univ.* **20**, 1-10.

Veletone , I. 1972 Bauxite: Elsevier, Amsterdam 1-226.

Veletone, I. 1981 Bauxite on Peneplained metamprphic and magmatic rocks on setrital sediments and on karst topography, their similarities and contrasts of genesis. In: Lateritization. Proceed. Intemat. Sem. Laterization Processes, India Dec. 11-14,1979.

Whiteny, G. Abbas, S. Q. and Esposito, K. 1990 Mineralogy and Thermal Properties of clay deposits in the Salt Range and Kala Chitta Range, Punjab Province, Pakistan. *Geol. Surv. Pakistan Project. Rep.* (IR) PK-**96**, 1-34.