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Sedimentology and reservoir characterization of Permo-Triassic Gondwana sediments deposited around Bahadurganj, Purnea Basin

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Abstract

Permo-Triassic Gondwana sediments deposited around Bahadurganj are divided into five mapable units representing five formations. The Lower Gondwana Group (Permian) overlying the basement, covers Karandighi, Salmari, Katihar and Dinajpur formations. Upper Gondwana Group (Triassic) comprises of Lahil Formation and overlain by Siwalik Group sediments (Middle Miocene to Pliocene) with an unconformity. Among these, the Karandighi and Salmari formations are represented by fine grained argillaceous sandstone interbedded with coal and carbonaceous shale. Dinajpur and Katihar formations are mainly made up of coarse grained sandstone inter-bedded with siltstone, coal and shale/claystone. Petrographically, the sandstones are mainly sub-feldspathic quartz wacke. SEM studies show poor reservoir quality of sandstone owing to abundant kaolinite clay matrix. Alteration of feldspar to kaolinite coupled with mica flakes in intergranular space and minor quartz overgrowth are the important diagenetic imprints. This has caused deterioriation of the reservoir properties. Lahil Formation of Upper Gondwana mainly comprises silt to very coarse grained, poorly sorted sandstone with minor claystone beds. Petrographically, sandstone is quartz wacke with abundant kaolinite. The illite, and smectite are the other clay minerals present in the pore spaces which affect the reservoir quality. The coarser fractions as sandstone were transported mainly by tractive currents, constituted point-bars and channel-bars of the Gondwana river and the finer fractions were deposited from suspension in the interchannel floodplain areas.

The Siwalik Group consists of sandstone with minor claystone beds in the upper part and mainly claystone with interbeds of sandstone in lower part. Microfacies identified in this formation are micaceous quartz wacke and calcareous quartz arenite. Due to poor induration, the sandstone has better reservoir characteristic and were mostly deposited under fluvial conditions.

Introduction

The Purnea basin is a polycyclic rift basin located in the eastern part of Indo-Gangetic plain in Bihar and West Bengal continuing further eastwards to the Bangladesh border and beyond. Tectonically it can be classified as an intracratonic rift basin with an approximate thickness of about 4000m of sediments ranging in age from Permo-Carboniferous to Recent. The basin is bounded and separated from the Ganga Basin in the west by Monghyr - Saharsa ridge, whereas in the east it is bounded by the Kishanganj Fault. The south and northern extents of the basin are bounded by the Malda High and Main Boundary fault respectively (Bhowmik, 2009).

The Gondwana sediments deposited around Bahadurganj are divided into five mapable units representing five formations. The Lower Gondwana Group (Permian) overlying the basement, covers Karandighi, Salmari, Katihar and Dinajpur formations. Upper Gondwana Group (Triassic) comprises of Lahil Formation and overlain by Siwalik Group of sediments (Middle Miocene to Pliocene) with an unconformity marked at depth 1972m from surface. The study is aimed to delineate the Gondwana sediments and their reservoir quality for hydrocarbon prospectivity in Purnea basin. Lithology is described based on the study of drill cuttings and conventional cores along with electro-log attributes.

Experimental Details

The subsurface data from the wells drilled down to the Basement penetrating Gondwana sequences have been studied to identify the reservoir characteristics and depositional environments of sediments

deposited in the area. The biostratigraphic data have been taken into account for demarcating age boundaries. The electrologs were used for depth calibration of cores and cutting samples.
Megascopic and thin section petrographic studies were carried out using binocular stereo zoom microscope and petrological microscope to infer lithology, structures, microfacies, texture, matrix and cement content. Selected samples were analysed for clay mineral identification using X-ray diffraction technique. SEM analysis of representative samples of reservoir facies from different formations was carried out to understand fabric, grain-pore relationship and effect of clay minerals on porosity, permeability and reservoir quality.

Results and Discussion

In subsurface, wells drilled in Bahadurganj, Purnea basin up to depth of 2895m encountered 879m thick Gondwana sequence. The palynological evidences for these sediments suggest Early Permian to Triassic age. The whole Gondwana sequence is characterised by alternations of sandstone, siltstone, shale and coal. Division of Gondwana Group has been further divided into various formations based on lithofacies, palynological data and electro log characters (Fig.1).

Basement: The basement is represented by granite, which is leucocratic to mesocratic having phaneritic texture consisting of quartz, orthoclase and minor plagioclase feldspar, biotite and augite (Fig.2A).

Lower Gondwana

Karandighi Formation: The lower part of the Early Permian section is comprises of sandstone inter-bedded with coal and carbonaceous shale. Sandstone is dirty grey, moderately hard and compact. Petrographically, sandstone is sub-feldspathic quartz wacke containing fine to medium, moderately sorted, quartz grains and fresh as well as altered microcline feldspar mica minerals and kaolinite clay matrix (Fig.2B).

Salmari Formation: This formation is represented by inter-bedded sandstone and coal/coaly shale. Sandstone is dirty white to gray, moderately hard and compact consisting of transparent to translucent, fine to medium grained, moderately sorted, sub angular to sub rounded quartz grains and mica minerals. Petrographically, sandstone is sub-feldspathic quartz wacke. Microcline and orthoclase feldspars are fresh as well as altered into kaolinite (Fig.2C). Clay mineral analysis of carbonaceous siltstone depicts the presence of kaolinite with traces of illite (Fig.7A).

Katihar Formation: The formation is made up of sandstone inter-bedded with coal and shale. Sandstone is dirty white to brownish grey, moderately hard and compact. Shale is variegated yellow, brownish yellow to gray, soft to moderately compact. Thin section petrography of cutting sample illustrates that sandstone is feldspathic to sub-feldspathic quartz wacke and contains fine to coarse grained poorly sorted quartz grains (Fig.2D) embedded in kaolinitic and micaceous clay matrix. SEM analysis of sample at depth 2765m shows the presence of abundant kaolinite clay as matrix and alteration of feldspar to kaolinite are the factors affecting reservoir quality adversely (Fig.3& 4).

Dinajpur Formation: The interval is mainly made up of sandstone inter-bedded with coal and shale. Sandstone is soft and friable quartz, muscovite and biotite. Petrographically the sandstone is sub-feldspathic quartz wacke containing silt to fine grade occasionally medium grained, moderately well sorted quartz grains. Feldspars are fresh and altered orthoclase, microcline and minor plagioclase. Matrix is composed of kaolinite and sericitised mica (Fig.2E), at places patchy calcite cement corroding biotite.

Upper Gondwana

Lahil Formation: This formation is mainly represented by sandstone with minor claystone beds. Sandstone is off white to dirty brown with greenish tinge, soft and friable containing quartz, mica and off white clay. Claystone is variegated brown and grey, soft and micaceous. Petrographically sandstone is quartz wacke containing silt to very coarse grained, poorly sorted quartz grains along with silty clay matrix (Fig.2F), At times, sandstone contains abundant kaolinitic clay matrix. Clay mineral analysis from XRD is shows the presence of kaolinite clay mineral (Fig.7B). SEM studies reveal that sandstone is having moderate reservoir characteristics retaining some intergranular

porosity (Fig.5). The porosity is partially deteriorated by the presence of abundant kaolinitic matrix (Fig.6).

Conclusions

Permian sediments of Lower Gondwana sub group were deposited on granitic basement. The Lower Gondwana sub-group comprises four formations - Karandighi, Salmari, Katihar and Dinajpur in a depositional order. Lower Gondwana sediments consist of poorly sorted quartz grains ranging in size from fine to very coarse, occasionally granules might be due to fluctuation in fluvial energy. Feldspathic to sub-feldspathic microfacies of sandstone suggesting cold climate deposition, in which preexisting rocks disintegrate but doesn't decompose as a result less resistant minerals like feldspars are preserved. On the other hand, presence of carbonaceous matter/coal suggests warm climatic conditions. Keeping these two in mind it is concluded that Lower Gondwana sediments were deposited in fluctuating environmental conditions which cause partial decomposition of feldspar into kaolinite which is filled in the pore spaces and reduced the porosity and permeability of the reservoir rocks. Top of the Dinajpur Formation is sandstone with variegated reddish brown to grey claystone, which might be due to arid desertic climatic condition suggesting an unconformity which separates Upper Gondwana from Lower Gondwana sub group.

Upper Gondwana sub group comprises of only Lahil Formation consisting of sandstone and claystone. Sandstone is loosely bound and consists of moderately sorted, quartz grains and kaolinitic clay matrix. It has moderate porosity and permeability due to absence of cementing material. Top of the formation is dominated by reddish brown claystone marking an unconformity between Upper Gondwana and Lower Siwaliks.

The Siwalik Group consists of sandstone with minor claystone beds in the upper part and mainly claystone with interbeds of sandstone in lower part. Microfacies identified in this formation are micaceous quartz wacke and calcareous quartz arenite. Due to poor induration, the sandstone has better reservoir characteristic and were mostly deposited under fluvial conditions.

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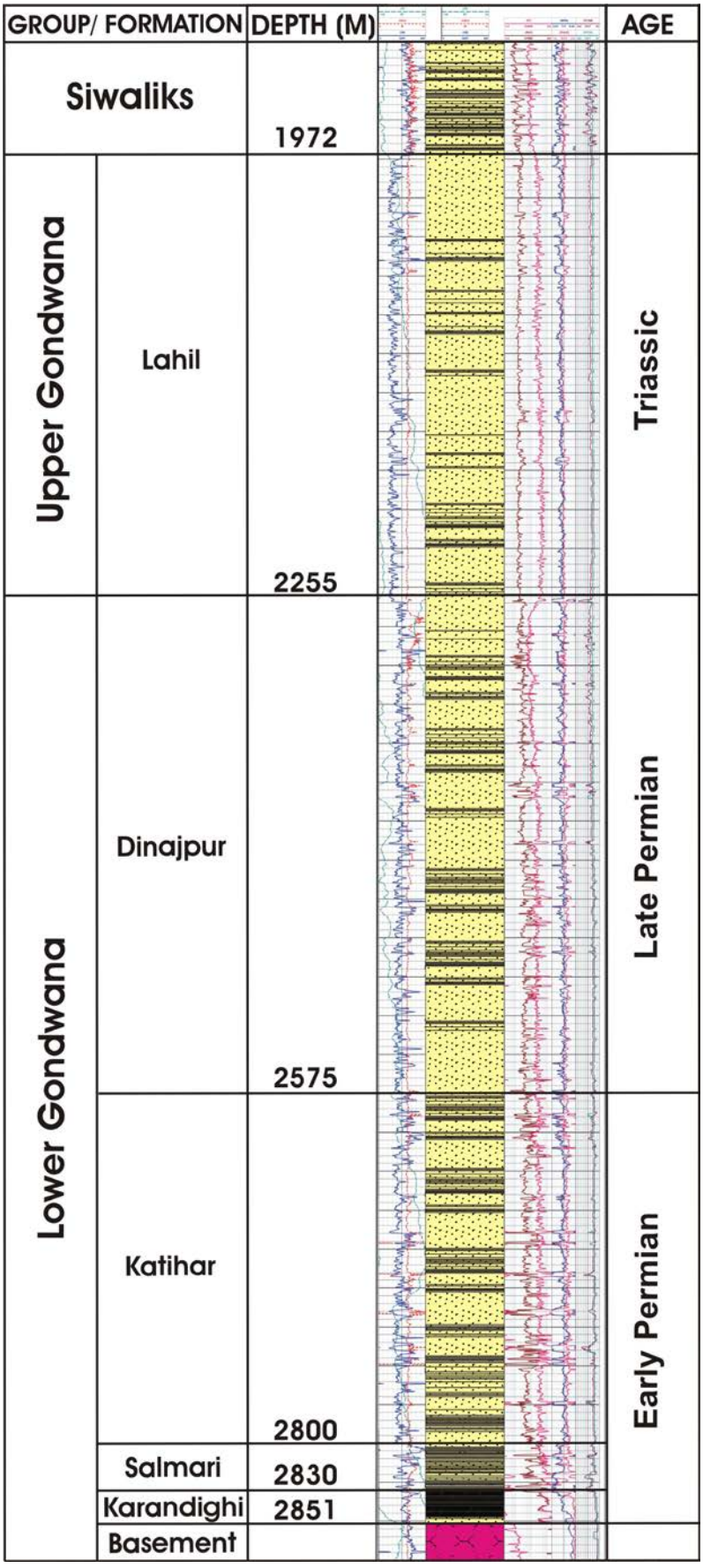


Fig. 1: Divisions of Gondwana based on lithofacies and electrolog attributes

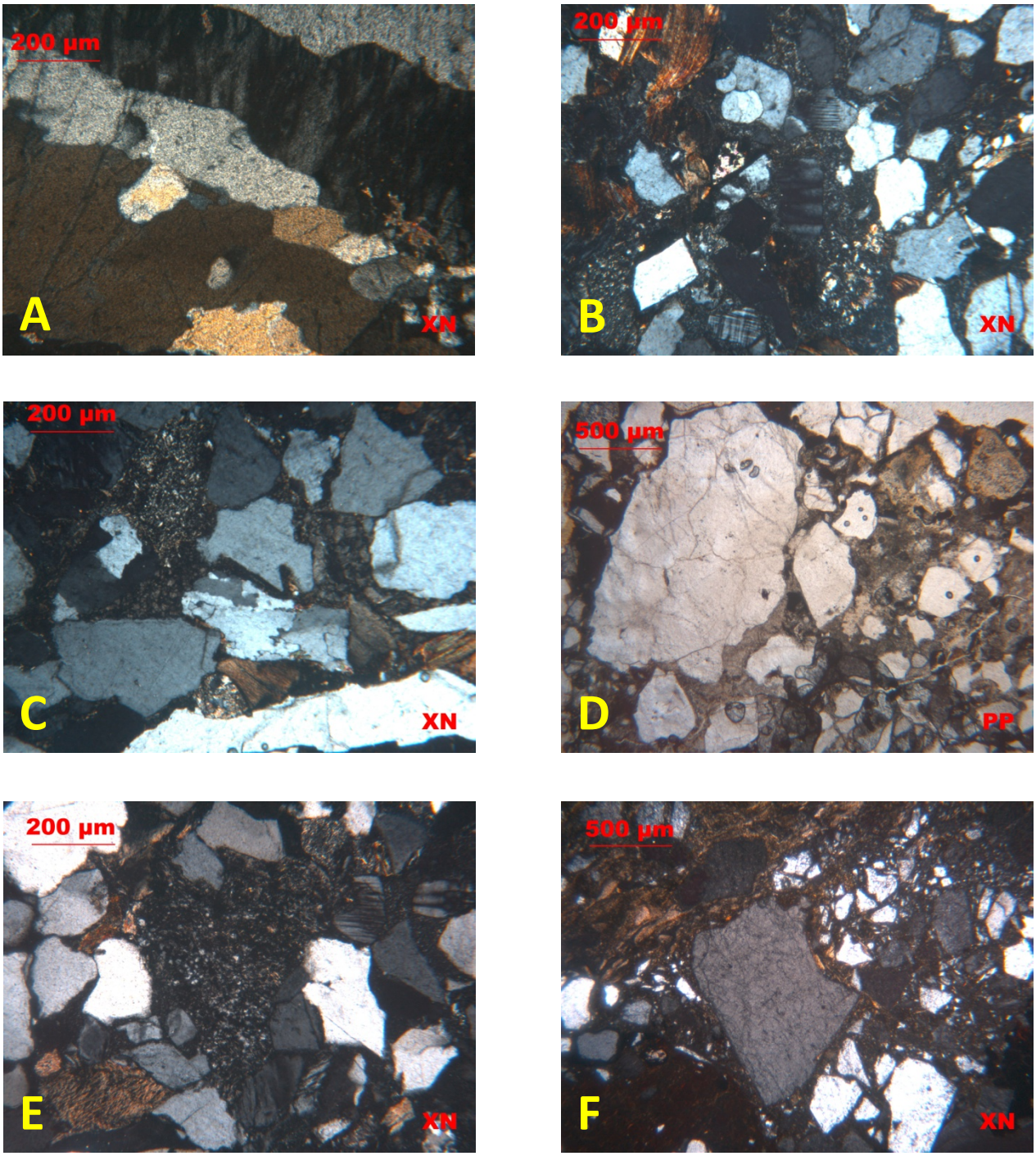


Fig.2. Petrographic attributes. (A) **Perthite texture:** Intergrowth of orthoclase and plagioclase (2875-2880m, Granitic Basement). (B) **Sub-feldspathic quartz wacke** containing microcline feldspar, mono and poly-crystalline quartz and kaolinite clay matrix. (2835-40m, Karandighi Formation). (C) **Sub-feldspathic quartz wacke showing quartz overgrowth,** containing quartz, kaolinite clay and rock fragments (2810-15m, Salmari Formation). (D) **Sub-feldspathic quartz wacke** showing poorly sorted quartz. (2670-75m, Katihar Formation). (E) **Sub-feldspathic quartz wacke** consists of quartz,kaolinite clay, altered biotite and feldspar (2425-30m, Dinajpur Formation). (F) **Quartz wacke** containing silt to very coarse grained, poorly sorted, quartz grains along with silty clay matrix (1990-95m, Lahil Formation).

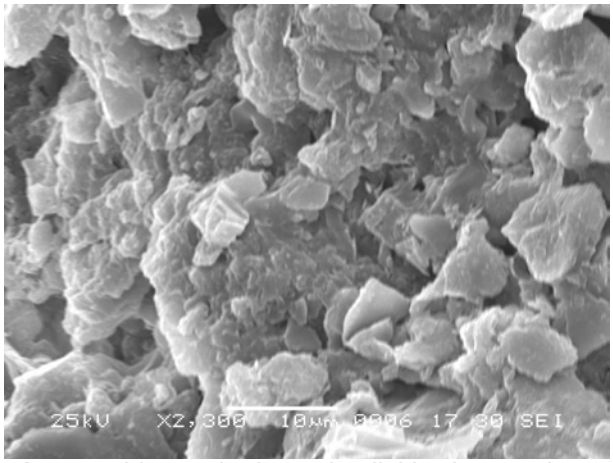


Fig. 3: Feldspar altering to kaolinitic clay matrix and reducing porosity. (Katihar Formation, Lower Gondwana)

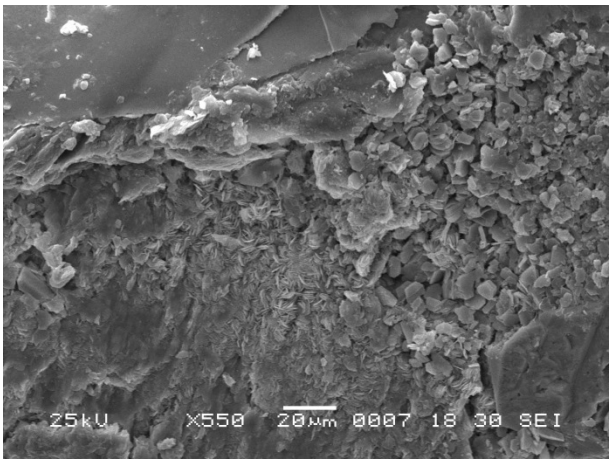


Fig. 4: Pore filled kaolinite clay reducing the porosity. (Katihar Formation, Lower Gondwana)

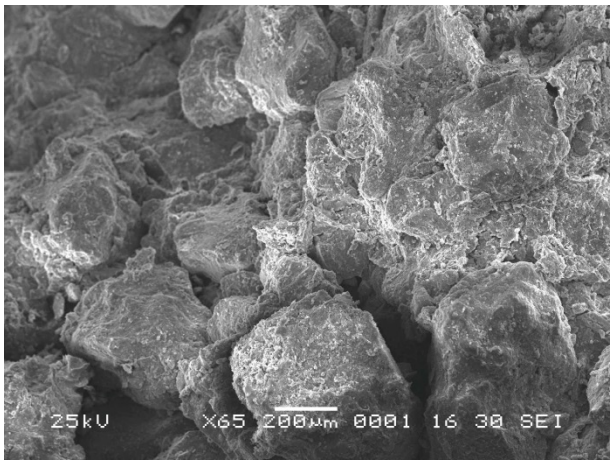


Fig. 5: General view showing moderate intergranular porosity. (Lahil Formation, Upper Gondwana)

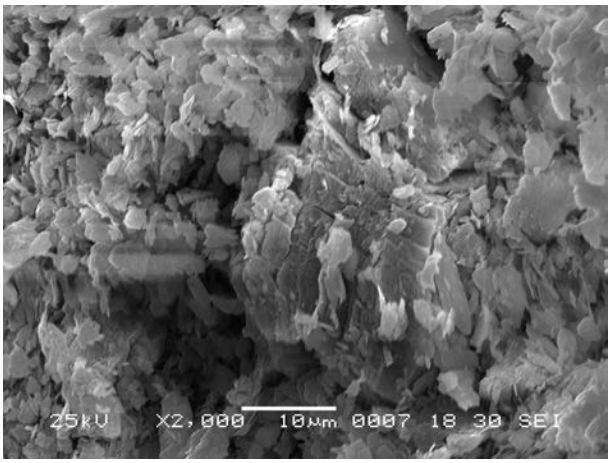
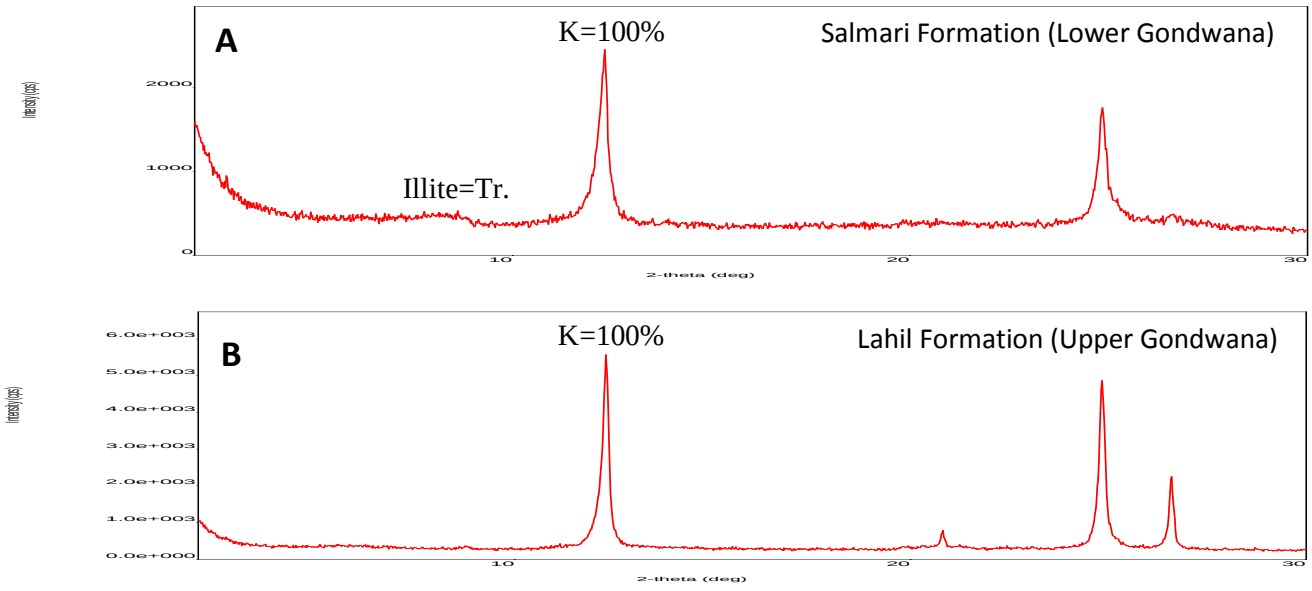


Fig. 6: Feldspar altering to kaolinite. Matrix porosity can be seen between grains. (Lahil Formation, Upper Gondwana)



I=Illite, and K=Kaolinite

Fig. 7 Clay mineral analysis of Gondwana Group sediments