RESEARCH ARTICLE

Revised Stratigraphy of Indus and Balochistan Basins (Pakistan): Sea level changes and Land-Ocean connections of Mesozoic and Cenozoic strata

Muhammad Sadiq Malkani*,1, Muhammad Imran Alyani2, Mureed Hussain Khosa3,4 Faisal Saeed5, Ameena Haroon3, Muhammad Aslam Buzdar3 Ahmed Shah Kakar5

1Geological Survey of Pakistan, Muzaffarabad, Azad Kashmir, Pakistan.
2Geological Survey of Pakistan, Lahore, Pakistan.
3Faculty of Marine Sciences, Lasbela University of Agriculture, Water and Marine Sciences, Uthal, Balochistan, Pakistan
4China University of Geosciences, Beijing, China
5Center of Excellence in Mineralogy, University of Balochistan, Quetta

Abstract:- Indus basin which is a part of Gondwana represents significant Mesozoic and especially Cretaceous marine and also non-marine deposits. Balochistan basin is a part of Neotethys represent Cretaceous and mostly Cainozoic strata. The uppermost/northernmost/Khyber-Hazara-Kashmir and also upper/north/Kohat-Potwar basins show marine to terrestrial strata of Precambrian to recent. The stratigraphy of middle/central/Sulaiman basin shows mostly Triassic to Latest Cretaceous as marine, Latest Cretaceous (Vitakri Formation) as terrestrial, Paleocene as marine, Early Eocene-Middle Eocene as deltaic, terrestrial and marine, Oligocene to recent as terrestrial. The lower/south/Kirthar basin shows marine stratigraphy from Triassic to Oligocene and then at the end of Oligocene the Tethys permanently closed and terrestrial or continental strata came into existence, however the Jurassic-Cretaceous and Cretaceous-Tertiary boundary show at places continental disconformity and at places marine.

Keywords: Revised Stratigraphy, Sea level changes, Land-ocean linkage, Kirthar/lower Indus, Sulaiman/middle Indus, Kohat-Potwar/upper Indus, Khyber-Hazara-Kashmir/uppermost Indus, Balochistan Basin, Pakistan.

INTRODUCTION

Indus basin is located in the central and eastern part of Pakistan and further subdivided into uppermost (Khyber-Hazara-Kashmir), upper (Kohat-Potwar), middle (Sulaiman) and lower (Kirthar) basins. Indus basin situated in the west and north of Indo-Pak subcontinent which belongs to Gondwana lands (southern earth). The Balochistan Basin is located in the southwestern part of Pakistan. The sediments of Pakistan underwent significant tectonic deformation during the collision of Asian and Indo-Pak continental plates that started in the latest Cretaceous; as result strata have been field folded, faulted and elevated along with many many variations of sea level and land-ocean connections (Fig.1). Goals of the present study are to present handy and brief information based on previous and recent wide spread works.

MATERIAL AND METHOD

The materials belong to compiled data from previous work and also field data collected by senior author during many field seasons (Fig.1). The methods applied here are many discipline of purely geological description.

*Corresponding author: malkanims@yahoo.com
RESULTS AND DISCUSSION

Revised Stratigraphy of Khyber-Hazara-Kashmir (Uppermost Indus) Basin

The uppermost Indus basin is the lateral extension of Upper Indus basin in the downward slopes. In the upper Indus basin the alternating terrestrial and marine conditions were dominant while in the uppermost Indus basin the marine conditions were common. For example in the case of terrestrial Datta Formation which is terrestrial and thick in upper Indus while mostly marine and thin in uppermost Indus (only a few meter sandstone is observed in Nathiagali section). The comprehensive and revised stratigraphic setup of Khyber-Hazara-Kashmir (uppermost Indus) basin represents Precambrian Hazara (slates with some dolomitic limestone) Formation and Tanawal Quartzite; Cambrian Abbottabad (dolomite/dolomitic limestone) and Hazira formations (glauconitic, chamositic, iron bearing strata); Triassic Chalk Jabbi (limestone/dolomite); Jurassic Datta (mostly sandstone) and Samanasuk (mainly limestones) formations; Cretaceous Chichali (shale/mudstone) and Kawagarh (limestones) formations in southern part while in northern part the Panjal Formation including volcanics and slates/phylite with some marbles; Infra Tertiary boundary (Latest Cretaceous to old) represented as Indus Formation (bauxite, glauconite, chamosite, laterite); Latest Cretaceous to Late Paleocene Hangu (shale, sandstone, ironstone and coal; Patala is a synonym and lateral facies of Hangu Formation; its age is Latest Cretaceous to Early Paleocene because it is well correlated with the Vitakri coal of Kingri area of Sulaiman basin), Paleocene Lockhart (fine nodular limestones), Eocene (probably Late Paleocene) Nammal (Kuzagali shale) and Sakesar (coarse nodular limestones) formations; Eocene Kuldana Group (first clastic material in this basin derived from north, showing first and feeble collision of Indo-Pak plate with Asia) represents Chorgali (fine clastic; shale and limestone/dolomite) and Kuldana (red and varicoloured mudstone, sandstone and dolomitic limestone; lower...
Kuldana is mostly continental correlated with Toi and Kingri formations of middle Indus while upper Kuldana show transgression of sea and correlated with Habib Rahi, Domanda, Pirkoh and Drazinda formations of Kahan group of Middle Indus (formations; Miocene-Pliocene Murree formation (fine to coarse clastic showing hard collision of Indo-Pak with Asia); Soan Group represents Pleistocene Lei (mainly conglomerate-coarse clastic facies) and Holocene Soan (clay, sandstone and subordinate conglomerate-relatively fine clastic facies) formations. Further there are problems in correlating Murree, Kamlial, Chinji, Nagri, Dhok Pathan especially in Azad Kashmir and northern Potwar. So Murree Formation is senior synonym of Kamlial and also coeval and lateral variations of Chinji (Lower Murree), Nagri (Middle Murree) and Dhok Pathan (Upper Murree). The relative thickness of lower and middle parts of Murree are relatively very small than upper Murree in the Kashmir and Hazara. So revised sequence in Khyber-Hazara-Kashmir areas is Murree and Soan formations, and in Potwar areas are Chinji, Nagri and Dhok Pathan formations of Potwar Group. In Khyber area, the formation names are rich based on local names, it needs to revise with Hazara-Kashmir area of uppermost Indus basin. Like the Hindukush-Karakoram, Kohistan-Ladakh, the Khyber sub basin exist many local names for strata, so it needs further detail revision.

Revised Stratigraphy of Kohat-Potwar (Upper Indus) Basin

Indo-Pakistan shield represents Precambrian Nagar Parker granite in the southern/Lower Indus while the Kirana group (slate, quartzite and igneous rocks) in the northern/Upper Indus. Kohat-Potwar basin represents Precambrian Salt Range (marl, gypsum, salt and shale) Formation, Cambrian Khewra (purple to brown sandstone), Kussak (greenish grey and glauconitic sandstone), Jutana (light green dolomite and shale), Baghanwala (red shale alternated with flaggy sandstone), Khisor (gypsum with shale and dolomite), Permian Tobra (tillite conglomerate, sandstone), Dandot (sandstone and shale), Warcha (sandstone with some shale) and Sardhi (shale with minor sandstone and siltstone) formations; Miocene-Pliocene Murree formation (fine to coarse clastic showing hard collision of Indo-Pak with Asia); Soan Group represents Pleistocene Lei (mainly conglomerate-coarse clastic facies) and Holocene Soan (clay, sandstone and subordinate conglomerate-relatively fine clastic facies) formations. Further there are problems in correlating Murree, Kamlial, Chinji, Nagri, Dhok Pathan especially in Azad Kashmir and northern Potwar. So Murree Formation is senior synonym of Kamlial and also coeval and lateral variations of Chinji (Lower Murree), Nagri (Middle Murree) and Dhok Pathan (Upper Murree). The relative thickness of lower and middle parts of Murree are relatively very small than upper Murree in the Kashmir and Hazara. So revised sequence in Khyber-Hazara-Kashmir areas is Murree and Soan formations, and in Potwar areas are Chinji, Nagri and Dhok Pathan formations of Potwar Group. In Khyber area, the formation names are rich based on local names, it needs to revise with Hazara-Kashmir area of uppermost Indus basin. Like the Hindukush-Karakoram, Kohistan-Ladakh, the Khyber sub basin exist many local names for strata, so it needs further detail revision.
extension of Sulaiman basin stratigraphy. Pezu to Parachinar (Kurram agency) is an interfingering of strata of middle and upper Indus basins (Malkani and Mahmood in process).

Revised Stratigraphy of Sulaiman (Middle Indus) And Kirthar (Lower Indus) Basins

Sulaiman basin shows the different updated lithological units (Malkani 2004, 2010a, 20112012, 2015a) in ascending order (Fig.1) are; Triassic Khanozai group represents Gwal (shale, thin bedded limestone) and Wulgai (shale with medium bedded limestone), Jurassic Sulaiman group represents Spingwar (shale, marl and limestone with some igneous sills/dykes found close to western Indus Suture), Loralai (limestone with minor shale), and Chiltan (limestone) formations, Cretaceous Parh Group represents Sembar (shale), Goru (shale and marl), and Parh (limestone with some volcanic sills/dykes found close to western Indus Suture) formations, and Fort Munro group represents Mughal Kot (shale/mudstone, sandstone, marl and limestone with some volcanics found close to western Indus Suture), Fort Munro (limestone), Pab (sandstone with subordinate shale with some evidences of Deccan volcanism) and Vitakri (red muds which is the host of dinosaurs and grey to white sandstone; Malkani 2006, 2009, 2010b, 2015b) formations, Paleocene Sangiali group represents Sangiali (limestone, glauconitic sandstone and shale), Rakhi Gaj (Girdu member, glauconitic and hematitic sandstone; Bara (sandstone with minor limestone, coal and volcanics) and Lakhra (limestone and shale) formations; Early Eocene Chamalang/Ghazij group (north source) in northern Kirthar while Laki Group (lateritic clay, ochre, coal and limestone of Sohnari and shale and limestone of Laki formations; east source) in southern Kirthar; and Kirthar (shale and limestone) and Gorag (mainly resistant limestone) formations of Kirthar Group and Oligocene Gaj Group represents Nari (ferruginous sandstone, shale, limestone) and Gaj (shale with subordinate sandstone and limestone) formations and Miocene-Pliocene Manchar (sandstone, conglomerate and mud) group, and Subrecent and Recent surficial (alluvium, colluvium, eolian, lacustrine, evaporite) deposits.

Revised Stratigraphy of Balochistan Basin And Correlation With Sulaiman/Middle Indus Basin

The Balochistan basin is subdivided into Chagai-Raskoh-Wazhdad magmatic arc, Kakar Khorasan (back arc marginal flysch
and molasses basin) and Makran-Siahan (fore arc; arc-trench gap) basin (Malkani 2011,2014). The **Chagai-Raskoh-Wazhdad magmatic arc** shows the Cretaceous Chagai intrusions which is invaded by Sinjrani Volcanic Group (=Kuchaki), Cretaceous-Paleocene Nisai Group includes Akhtar Nika and Jabrai formations (Synonyms; Humai and Rakhshani formations; intercalations of shale, sandstone, siltstone and limestone in the middle and thick bedded to massive limestone at the top, andesitic lava flows and volcanics in arc basin) and Nisai Limestone(Synonyms;Robat/Kharan/Wakai limestones): Late Paleocene-Early Eocene Shagala Group includes Murgha Faqirzai and Mina formations (synonyms; Khojak/Saidak/Washap/Amalaf formation; shale, siltstone, sandstone, marl and limestone; andesitic lava flows and volcanics in arc basin), Late Eocene Shorkoh intrusions (dykes or sills but a few small lenticular stocks have been found in the region of Robat and Saidak, hypabyssal and intermediate diorite). Washuk Intrusions (granite exposed in the southern part of western Washuk range), Wazhdad Volcaniclastics Group and Washuk ophiolite, Oligocene-Pliocene Vihowa Group (synonyms; Malthanai/Dasht Murgha group) and Pleistocene-Holocene Sahgal Group, Oligocene-Pliocene Vihowa Group (synonyms; Malthanai/Dasht Murgha group) and Pleistocene-Holocene Sahgal Group, Late Pliocene to Pleistocene Khorasan group (synonyms; Chagai-Raskoh-Wazhdad arcs. It is correlated with Early Cretaceous Parh Group, Late Cretaceous Fort Munro Group and Paleocene Sangiali Group (Sangiali, Rakhi Gaj and Dungan formations) of Sulaiman basin (Malkani 2010a,2012). The Shagala Group is named after the village and area Shagala, 90km southwest of Zhob. The Shagala group consists of Late Paleocene-Earliest Eocene Murgha Faqirzai Formation (Shale, 2000m thick), Early Eocene Mina Formation (alternation of green shale unit and sandstone unit; 3000m thick) and Early Eocene Shagala Formation (=Shagalu; alternation of terrestrial (host of Pakitherium shagala Malkani et al. 2013) red shale unit and sandstone unit; 3000m thick). The Murgha Faqirzai Shale is correlated with Siahan group and Mina Formation is correlated with Panjgur formation of Makran basin (Malkani 2011). It is also correlated with Chamalang (Ghajiri) Group and Kahan Group of Sulaiman basin. The Oligocene-Pliocene Vihowa Group represents same formations as Sulaiman basin. It is correlated with Talar Group of Makran basin and Pishi Group of Chagai-Raskoh-Wazhdad magmatic arc. The
Pleistocene-Holocene Sakhi Sarwar (Boston; Kech) Group represents Dada Formation (well developed conglomerate with subordinate mud and sandstone) and Sakhi Sarwar (Boston) Formation (mud and sandstone with poorly developed conglomerate, while in centre of valleys the mud is dominant) concealed at places especially in the valleys and plain areas by the Subrecent and Recent fluvial, eolian and colluvial deposits.

Correlation of the Cainozoic Strata of Sulaiman Basin (Part of Gondwana) With Adjoining Northern Balochistan Basin (Part of Tethys), Pakistan

Sulaiman Basin is located in the middle part of Supper Indus Basin which belongs to an Indo-Pakistan subcontinent (A Gondwana Fragment). The Supper Indus Basin is subdivided in to Uppermost/northernmost Indus, upper/north Indus, middle Indus (Sulaiman) and lower/south Indus basins. Balochistan Basin is evolved under Tethys Sea. Balochistan Basin is subdivided into Chagai-Raskoh-Wazhad magmatic arc, northern Balochistan/Kakar Khorasan (back arc) and southern Balochistan/Makran (fore arc; arc-trench gap) basins. The Cainozoic of Sulaiman Basin is well correlated with adjoining northern Balochistan basin due to collision of Indo-Pakistan plate with Asian plate during Latest Cretaceous. Due to this terminal Cretaceous collision, the adjoining contact of northern Balochistan (Kaker Khorasan) Basin occurred with the Indus Basin especially Sulaiman/Middle Indus Basin. Due to this collision the birth of Paleo Indus River systems occurs and ended the dynasty of Paleo Vitaki River systems. The Paleocene Sangiali Group of Sulaiman Basin is well correlated with the Nisai Group of Balochistan especially the Nisai Limestone with the Dungan Limestone. In this way Early Eocene Shagala Group of Balochistan Basin is well correlated with the Chamalang/Ghazij Group (Shaheed Ghat-shale, Toi-sandstone and shale, Kingri-red muds and sandstone-Drug-rubblly limestone and Baska-gypsum and shale) and Kahan Group (Habib Rahi-limestone, Domanda-shale, Pirkoh-marl and shale and Drazinda-shale) of Sulaiman basin. The Murgha Faqirzai Formation (shale, 2000m thick) of Shagala Group is correlated with Shaheed Ghat shale of Sulaiman basin, the Mina Formation (alternation of green shale unit and sandstone unit; 3000m thick) of Balochistan is well correlated with Toi Formation of Sulaiman Basin, and the Shagala Formation (=Shagal; alternation of terrestrial red shale unit and sandstone unit; 3000m thick) of Balochistan basin is well correlated with the Kingri Formation of Sulaiman Basin. At the hard contact of Indo-Pakistan plate with Asia at the end of Eocene resulted in the form of the Oligocene-Pliocene Vihowa Group (synonyms; Malthanai/Dasht Murgha group) in both basins. The Vihowa Group represents Chitarwata (which is the host of Buzdartherium gulkrino-a baluchithere-the largest land mammals), Vihowa, Litra and Chaudhwan formations. So far last major tectonic episode occurred at Early Pleistocene which deposited the Pleistocene-Holocene Sakhi Sarwar Group (Boston formation) represents Dada (conglomerate) and Sakhi Sarwar (mud and sandstone with poorly developed conglomerate, while in centre of valleys the mud is dominant) formations well developed in both basins. The southern part of Kakar Khorasan basin shows flysch deposition like Murgha Faqirzai Shale and Mina Formation (green shale and sandstone) while the northern part of Kakar-Khorasan basin shows both these formations as flysch deposition while the middle-Late Eocene Shagala (Shaigalu) Formation (sandstone and red to maroon, brown shale and sandstone) as terrestrial/molase deposits which is supported by continental rhinoceros-baluchithere (Pakitherium Shagalai)-the largest land mammalian fauna.

REFERENCES


26
Pakistan Museum of Natural History (Pakistan Science Foundation), Islamabad, Pakistan, 63-66.


Received 10th Sep 2015 Accepted 12th Nov 2015
Manuscript can be viewed online at www.luawms.edu.pk