Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 41 (1) 107-118 (2009)

SURJ

Sindh Univ. Res. Jour.

EARLY TO MIDDLE JURASSIC RADIOLARIAN FAUNA FROM THE RAS KOH ARC AND ITS TECTONOSTRATIGRAPHIC SIGNIFICANCE

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(Received 12th March 2009 and Revised 06th May 2009)

Abstract

The Ras Koh arc is about 250 km long, 40 km wide and trends in ENE direction. The arc is convex towards southeast and terminated by the Chaman transform fault zone towards east. This arc is designated as frontal arc of the Chagai-Ras Koh arc system.

The Late Cretaceous Kuchakki Volcanic Group is the most wide spread and previously considered the oldest unit of the the Ras Koh arc followed by sedimentary rock formations including Rakhshani Formation (Paleocene), Kharan Limestone (Early Eocene) and Nauroze Formation (Middle Eocene to Oligocene). Dalbandin formation (Miocene to Pleistocene), and semi-unconsolidated Subrecent and Recent deposits. The Rakhshani Formation is the most wide spread and well-exposed unit of the Ras Koh arc. During the present field investigation the Rakhshani formation in the southeastern part of the Ras Koh arc, is identified as an accretionary complex, which is designated as Ras Koh accretionary complex. The Ras Koh accretionary comple is subdivided into three units: (a) Bunap sedimentary complex, (b) Charkohan radiolarian chert, and (c) Ras Koh ophiolite melange. The Bunap sedimentary complex is farther divided into three tectonostratigraphic units viz., northern, middle and southern. Each unit is bounded by thrust faults, which is usually marked by sheared serpentinites, except northern unit, which has gradational and at places faulted contact with the Kuchakki Volcanic Group. The northern unit is mainly comprised of allochthonous fragments and blocks of limestone, sandstone, mudstone and the volcanics in dark gray, greenish gray and bluish gray siliceous flaky shale. At places the shale is metamorphosed into phyllite. This unit is thrust over the middle unit, which exhibits relatively a coherent stratigraphy, represented by greenish gray calcareous flaky shale with intercalation of thin beds and lenticular bodies of mudstone, sandstone and limestone. The middle unit is again thrust over the southern unit, which is mainly composed of large exotic blocks of volcanic rocks, limestone, sandstone, mudstone and conglomerate embedded in dark gray, greenish gray and bluish gray siliceous flaky shale which is generally moderately argillized. The unit is thrust over the Kharan Limestone. During the present field investigation about 350 meter thick sequence of thin-bedded maroon and green chert intercalated with the siliceous flaky shale of the same colour is discovered within this unit, which is found in the southeastern part of the Ras Koh arc. This chert sequence occurs on the margins of a large exotic block (350m X 3 km) of volcaniclastic rocks of unknown origin, which makes an overturned syncline. This chert sequence is developed on its both limbs and has lower faulted contact with the Bunap sedimentary complex.

Two samples collected from this chert sequence yielded radiolarian fauna, which include *Parvicingula sp, Laxtorum sp., Parahsuum cf. simplum, Parahsuum sp., Nassellaria gen. et sp. indet., Hsuum cf. Matsuokai., Archaeospongoprunum sp., Nassellaria gen. et sp. indet.* and *Hagias gen. et sp. indet.Tricolocapsa sp. Hsuum sp. Ristola sp. Archaeospongoprunum sp.* and *Tritrabinate gen. et sp. indet.*. This radiolarian chert sequence represents the late Early to Middle Jurassic pelagic sediment deposited in Ceno-Tethyan ocean floor; prior to the inception of volcanism in the Ras Koh arc and accreted with the arc during Late Cretaceous to Eocene along with the Bunap sedimentary complex of Late Jurassic age.

Keywords: Jurassic radiolarian fauna; Ras Koh arc; tectonostratigraphic significance.

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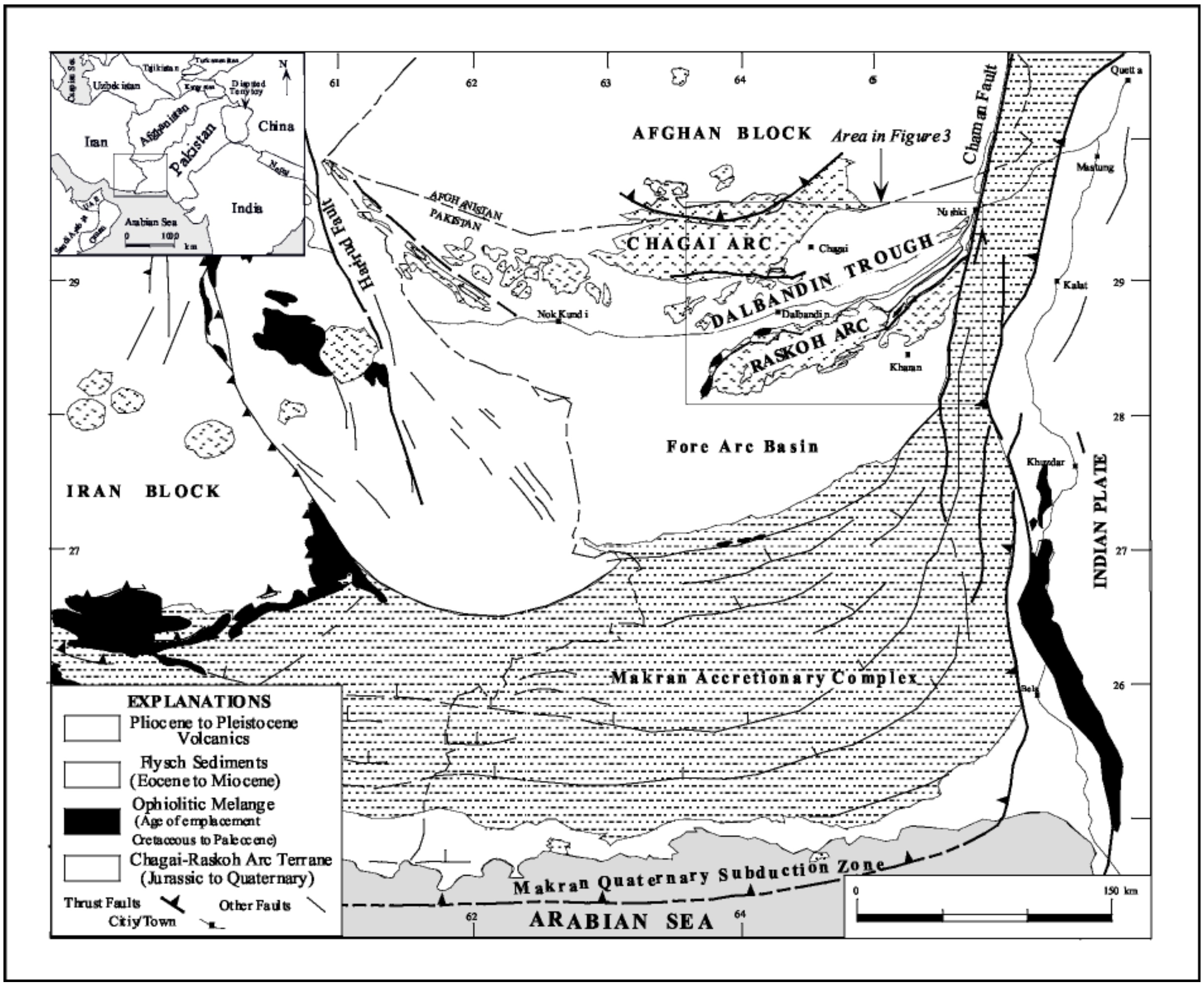
1. Introduction

The Ras Koh arc, which is also known as Ras Koh range or Ras Koh geanticline (Jones, 1960; Arthurton *et al.*, 1982), is now considered as frontal arc of the Chagai-Ras Koh arc system (Siddiqui, 1996). The arc is 250 km long, 40 km wide and trends in ENE direction. The arc is relatively a narrower topographic unit than the Chagai arc **(Fig. 1).** The Ras Koh arc is considered as fossil oceanic island arc, which was formed due to the intra-oceanic convergence in the Ceno-Tethys (Siddiqui, 2004).

Fig. 1. Geological map of Chagai-Ras Koh arc terrane, Balochistan, Pakistan (modifies and reproduced after Bakr and Jackson, 1964; Siddiqui, 1996).



The present study is the first of the systematic studies carried out in the region, which included 1:50,000 scale geological mapping, and detailed litho and biostratigraphic studies. One of the principal findings of this study include discovery of first ever radiolarian fauna from a sedimentary mélange unit, which was previously reported as Paleocene Rakhshani Formation by Jones (1960).

In this paper we are presenting brief geology of this region, including stratigraphy, lithology, faunal description and correlation of the newly discovered radiolarian fauna with the similar fauna found in the siliceous mudstone sequence found near Kohai village (Kojima *et al.*, 1993), which belongs to the lower sedimentary rock unit of a mélange zone occurring beneath the Muslim Bagh ophiolite complex of northeastern part of Balochistan.

2. Previous Work

Pioneer geological work in the Chagai-Ras Koh arc terrane was carried out by Vredenburg as early as 1901. Hunting Survey Corporation (H.S.C.) (1960) conducted reconnaissance study and geological mapping of the entire Balochistan province on 1: 253,440. During the seventies, many foreign geologists, including Sillitoe (1974), Nigell (1975), Dykstra (1978), Arthurton (1979) and Britzman (1979) visited the Chagai arc. This arc is considered to have formed on the southern leading margin of Afghan micocontinental plate (Stoneley, 1974; Sillitoe, 1978; Dykstra, 1978; Arthurton *et al.*, 1979; Spector and Associates, Ltd., 1981; Farah *et al.*, 1984; Arthurton et al., 1982; Kazmi and Jan, 1997). Ahmed (1984) also upheld a similar view on the basis of major elements chemistry of some acidic intrusive rocks. McCormik (1986) and Siddiqui (1996) have contradicted this viewpoint. Whence the former has proposed accretion of oceanic islands to form the Ras Koh arc, the latter consider it as the frontal arc of Chagai-Ras Koh arc system.

3. Geological Setting

The Ras Koh arc is bordered towards north by Dalbandin trough, terminated by Chaman fault on the east, whereas its southern and western margins are concealed by Quaternary alluvium and sand deposits of Kharan desert, which is also known as fore arc basin **(Fig. 1).** The NE-SW trend of the Ras Koh arc, contrary to the EW trend of Chagai arc is attributed to the Oligocene-Miocene north ward dragging of the eastern part of the arc by the left-lateral movement of the Chaman Fault (Abdel-Gawad, 1971). About 150 km wide and 300 km long area between Ras Koh arc and northern margin of Makran accretionary wedge (occupied by Miocene to Quaternary sediments) is the fore-arc basin. The area between the southern end of fore arc basin and up to the Makran coast is mainly occupied by flysch type sediments and is known as Makran accretionary zone (Jacob and Quittmeyer, 1979). This extraordinary thick accretionary zone was formed by the continuous northward accretion of marine sediments during Eocene to Miocene period and both the fore-arc basin and accretionary zone form one of the widest (450 km) arc trench gap on the earth.

Prior to the present study (Siddiqui, 2004) oldest rock unit in the Ras Koh arc was Kuchakki Volcanic Group (Cretaceous), which is followed in age by Rakhshani Formation (Paleocene) Kharan Limestone (Early Eocene), Nauroze Formation (Middle Eocene to Oligocene) and Dalbandin Formation (Miocene to Pleistocene) respectively. Subrecent and Recent alluvial deposits unconformably overly all the older formations. The stratigraphic sequence in the Ras Koh arc based on the recent study is presented in (**Fig. 2).**

4. Raskoh Accretionary Complex

The name Raskoh accretionary complex **(Figs. 2 and 3)** was first introduced by Siddiqui *et al.*, (1999) for three fault-bounded sedimentary rock units in the central Raskoh arc (Toposheet No. 34 H/5), which were identified as Late Jurassic in age. These rocks were previously mapped (H. S. C, 1960) as a part of the Paleocene Rakhshani formation. During the present study the Raskoh ophiolite melange (Bunap Intrusion of Jones, 1960) and Jurassic Charkohan radiolarian chert (Siddiqui *et al.*, 1999) are also included in the Raskoh accretionary complex, as both the rock units occur as thrust sheets within the complex. The following three divisions are proposed for the Raskoh accretionary complex: (a) Bunap sedimentary complex, (b) Charkohan radiolarian chert, and (c) Raskoh ophiolite melange.

a) Bunap Sedimentary Complex

The Bunap sedimentary complex is named after Bunap village (Toposheet No. 34 H/5) in the western Raskoh arc. This complex was previously reported as Rakhshani Formation by Jones (1960). The sedimentary complex stretches in NE-SW over 5 × 30 km area.

Fig. 2. Generalized stratigraphic sequence in the Chagai arc (based on Jones, 1960; Siddiqui, 1996; Siddiqui, 2004). The ages in the time scale are after Ogg *et al.* (2008).

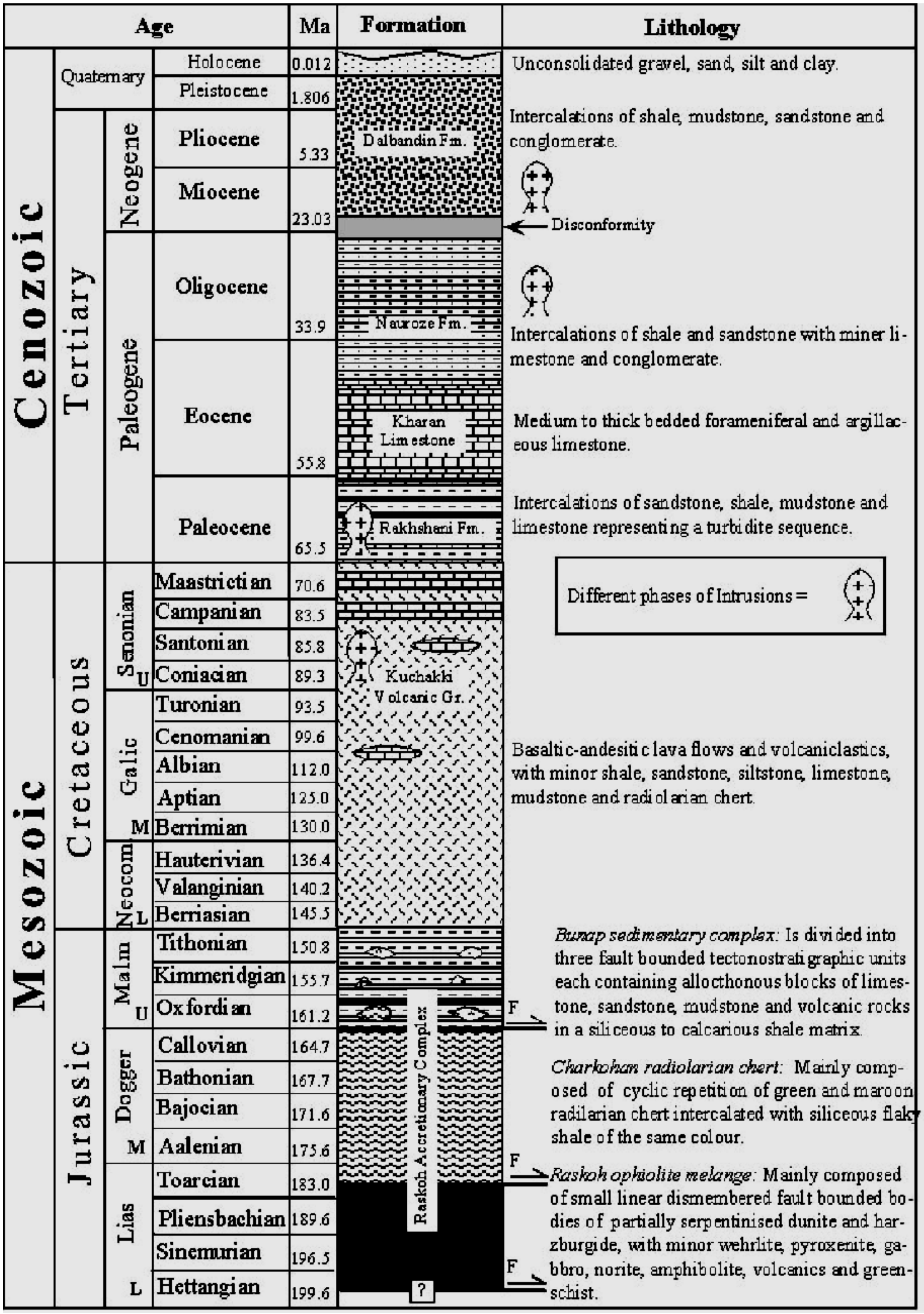


Fig. 3. Geological map of Ras Koh arc terrane, Balochistan, Pakistan (modifies and reproduced after Bakr and Jackson, 1964; Siddiqui, 2004).

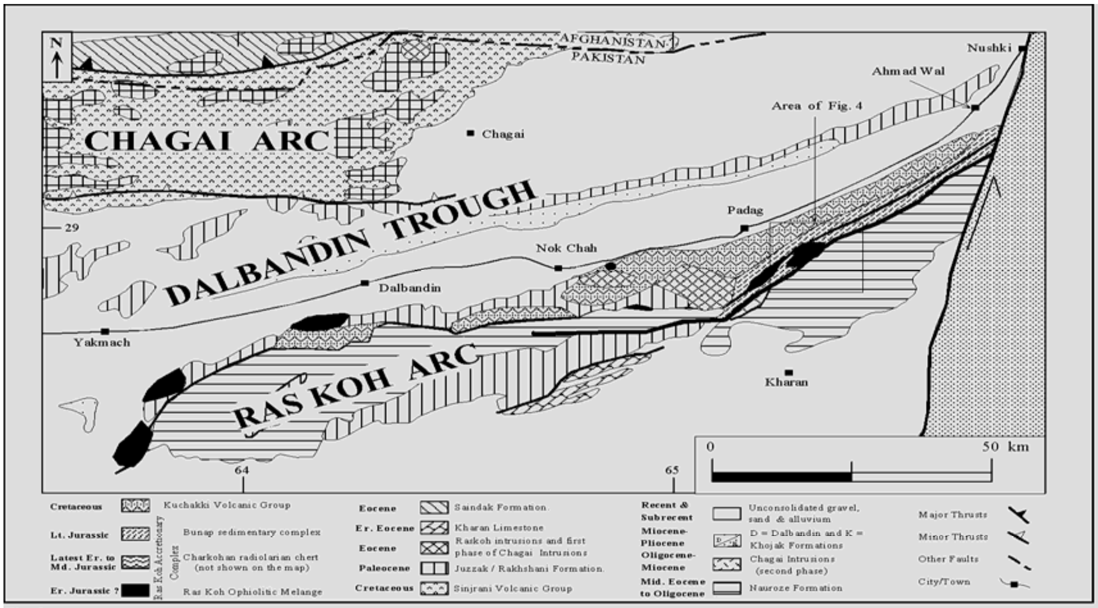


Fig. 3

Fig. 4. Geological map of Bunap area, Balochistan, Pakistan (modified and reproduced after Siddiqui and Haque, 1996).

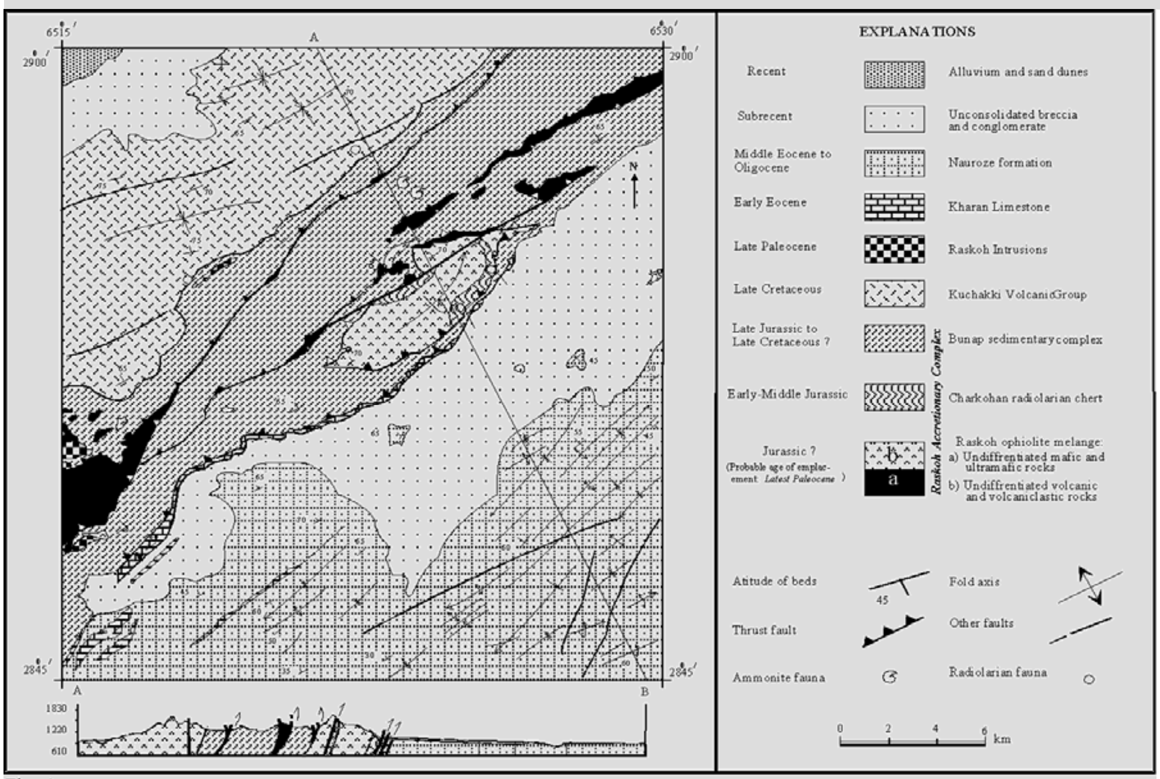


Fig. 4

The complex is mainly composed of flaky shale containing exotic blocks of sandstone, siltstone, mudstone, limestone and volcanic rocks. It is subdivided into three tectonostratigraphic units, each of which is bound by thrust faults, generally marked by sheared serpentinite **(Fig. 4),** except northern unit, which has gradational and at places faulted contact with the Kuchakki Volcanic Group. The northern tectonostratigraphic unit consists mainly of allochthonous fragments and blocks of limestone, sandstone, siltstone, mudstone, and volcanic rocks embedded in a greenish gray and dark gray siliceous flaky shale matrix **(Fig. 4).** At places the shale matrix is metamorphosed into phyllite or locally sericite schist. This unit is thrust over the middle tectonostratigraphic unit, represented mainly by greenish gray calcareous, flaky shale **(Fig. 5)**

Fig. 5. Thin bedded intercalated sequence of radiolarian chert and siliceous flaky shale belonging to the Charkohan radiolarian chert.

with intercalations and thin lenticular bodies of grayish green to black siltstone, mudstone and limestone. This sequence has two horizons of ammonite fauna **(Fig. 6)**. The middle unit commonly exhibits a relatively coherent internal stratigraphy as compared to the northern and southern tectonostratigraphic units. The southern unit is mainly composed of large (up to 12 × 3 km) exotic blocks of volcanic rocks, quartzose sandstone, conglomerate, siltstone, mudstone and limestone embedded in dark gray, greenish gray and bluish gray siliceous flaky shale intercalated with. The exotic blocks are boudinaged and display sheared boundaries with the matrix; hence this accretionary

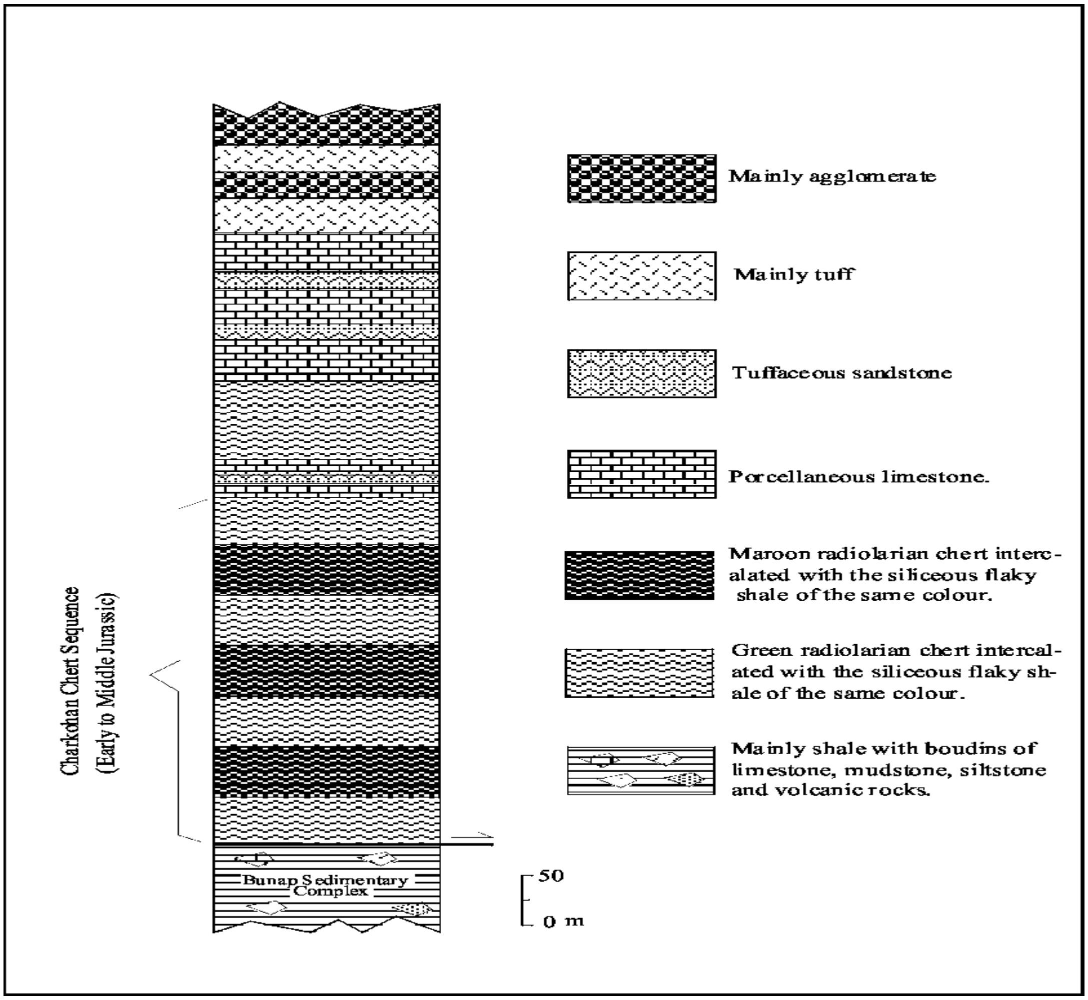
Fig. 6. Gravity folding in the chert intercalated shale sequence belonging to the Charkohan radiolarian chert.

complex may be termed as sedimentary mélange. This unit is thrust over the Kharan limestone of Eocene age. The Bunab sedimentary complex was probably deposited on the ocean floor of the Ceno-Tethys that once occurred between the newly dislodged collage of Cimmarian continent (Central Iran, Afghan blocks, Lhasa and West Burma) and the northern passive margin of Gondwana (Siddiqui, 2004).

b) Charkohan Radiolarian Chert

This chert sequence occurs on the margins of a large (350 m x 4 km) exotic block (boudin) of highly altered volcaniclastic rocks of unknown age and origin (most probably Jurassic oceanic crust). This block of volcaniclastic rocks is folded into an overturned syncline; hence the chert sequence is also present on its northern limb **(Fig. 4).** This chert sequence is about 350 m thick on the southern limb of the syncline. It is mainly represented by cyclic repetition of green and maroon radiolarian chert intercalated with siliceous flaky shale of the same colour **(Fig. 5 and 6).** The individual chert beds range in thickness from 3 to 15 cm. The chert unit grades upward into 30 m thick sequence of greenish grey porcellaneous limestone **(Fig. 7)**.

Fig. 7. Generalized internal stratigraphy of Charkohan radiolarian chert belonging to the Ras Koh accretionary complex.



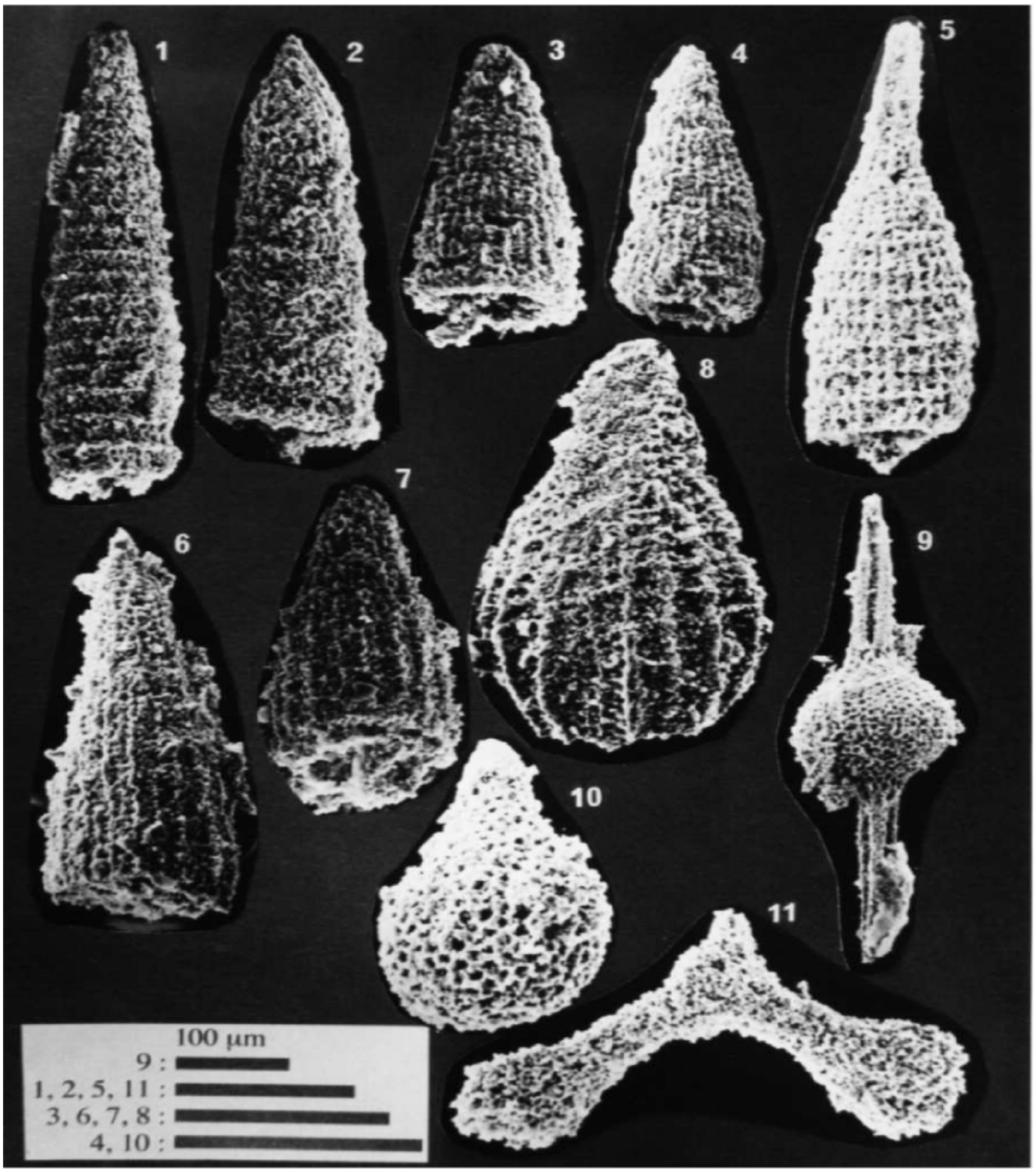
The limestone beds are 5 to 15 cm thick and are intercalated with dark brown tuffaceous sandstone. This limestone sequence is followed by a 70 m thick green radiolarian chert sequence intercalated with siliceous flaky shale of the same colour which is followed by another 150 m thick sequence of greenish grey porcellaneous limestone intercalated with thin beds of green and brown tuff. This limestone is followed by a volcaniclastic sequence represented by agglomerate, tuff, volcanic conglomerate and breccia. The limestone sequence also occurs on the northern limb of above-mentioned overturned volcanic block. This chert and limestone sequence is also associated with smaller exotic blocks of volcanic rocks in the northern and southern tectonostratigraphic units of the Ras Koh accretionary complex. This pelagic to hemi-pelagic sequence is considered to be deposited in the ocean floor of the Ceno-Tethys before the inception of intra-oceanic arc volcanism of the Ras Koh arc (Siddiqui, 2004).

Radiolarian Fauna: Two chert samples collected from the lower part of the Charkohan radiolarian chert yielded the following radiolarian fauna:

Sample No. RM-23 1 yielded: *Parahsuum cf. simplum* (Early Jurassic) *Parahsuum sp.* (Early Jurassic), *Hasuum cf. matsuokai* (Late Early to Middle Jurassic), *Parvicingula sp.* (Jurassic to Cretaceous), *Laxtoram sp.* (Jurassic to Cretaceous) and *Archaeospongoprunum sp.* (Jurassic to Cretaceous), *Hagiastrid sp.* (Jurassic to

Cretaceous) and *Nassellaria gen. et. sp. indet.* (Cenomanian to Turanian), *Tricolocapsa sp.* (Middle Jurassic) *Hsuum sp.* (early Late Jurassic) *Ristola sp.* (Middle to Late Jurassic) and *Tritrabinate gen. et sp indet.* (Jurassic to Cretaceous). Out of this radiolarian assemblage 11 relatively well preserved fossils are presented in **(Fig. 8).**

Fig. 8. Scanning electron photomicrographs of radiolarian fauna from the Charkohan radiolarian chert: 1) *Parvicingula sp.* (Jurassic to Cretaceous), 2) *Laxtoram (?) sp.* (Jurassic to Cretaceous), 3) *Parahsuum cf. simplum* (Early Jurassic), 4) *Parahsuum sp*. (Early Jurassic), 5) *Nassellaria gen. et sp. indet.* (Cenomanian to Turanian), 6) *Nassellaria gen. et sp. indet.* (Cenomanian to Turanian), 7) *Nassellaria gen. et sp. indet.* (Cenomanian to Turanian), 8) *Hasuum cf. matsuokai* (Latest early to Middle Jurassic), 9) *Archaeospongoprunum sp*. (Jurassic to Cretaceous), 10) *Nassellaria gen. et sp. indet.* (Cenomanian to Turanian) and *Hagiastrid gen. et sp. indet.* (Jurassic to Cretaceous).

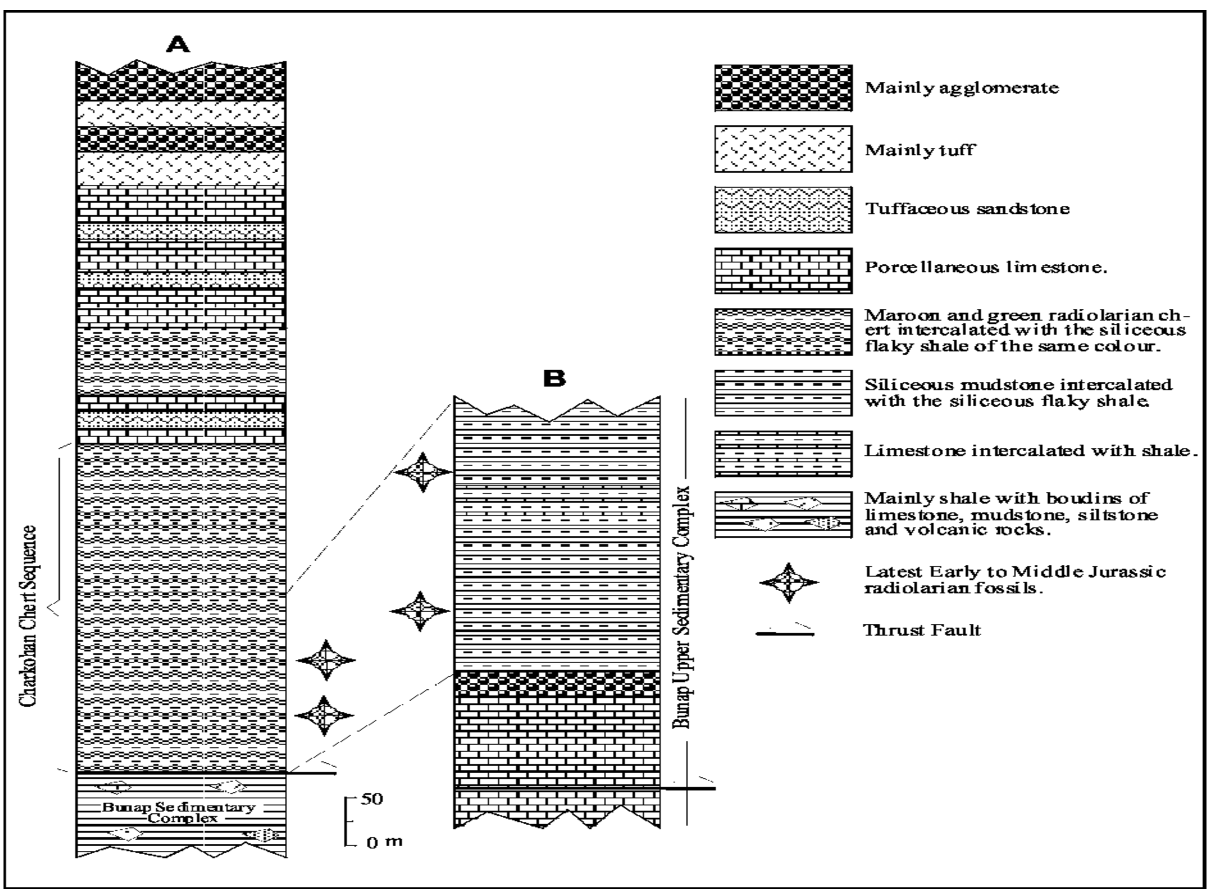


The sample No. RM-71B yielded very poorlypreserved *Tricolocapsa sp.* (early, Late Jurassic) and *Archaeodictyomitra spp.* (Late Jurassic to Early Cretaceous). Many radiolarian fossils from these samples are reported by Isozaki and Matsuda (1985) in bedded chert sequence in the Central Japan. The *Laxtoram sp.* and *Hasuum matsuokai* are included in the Early Jurassic *Laxtorum jurassicum* zone of Matsuoka and Yao (1986) and *hasume hisuikyoense* zone of Hori (1990), while *Tricolocapsa sp.* occur in the Middle Jurassic zones of Matsuoka and Yao (1986). The *Parahsuum cf. simplum* is found in Early Jurassic assemblage of Yao (1986) in SW Japan. There fore on the bases of the coexistence of *Tricolocapsa sp, Parahsuum cf. simplum, Hasuum cf. matsuokai* and *Laxtoram sp* a late Early to Middle Jurassic age is assigned to the lower part of the Charkohan radiolarian chert.

However it is inferred that the upper part of the Charkohan radiolarian chert, which has intercalations of porcellaneous limestone, chert and tuff, may be of Late Jurassic to Early Cretaceous age. In the light of this study it is suggested that the various rock assemblage of Ras Koh accretionary complex were formed during the Late Early Jurassic to Early Cretaceous.

On the basis of similar fauna, this part of the southern unit of the Ras Koh accretionary complex is correlated with a siliceous mudstone sequence found near Kohai village (Kojima *et al.,* 1994) which belongs to the lower sedimentary rock unit of a mélange zone occurring beneath the Muslim Bagh ophiolite complex, in the northeastern part of Balochistan province of Pakistan **(Fig. 9).**

Fig. 9. A comparison of columner stratigraphic sections: A) Charkohan chert sequence in the Ras Koh arc and B) Upper sedimentary rock unit (after Kojima *et al.*, 1994; Naka *et al.*, 1996) of Bagh complex in Muslim Bagh area.



c) Ras Koh Ophiolite Melange

These rocks were previously mapped as Bunap intrusions (Jones 1960) and described as mafic and ultramafic ophiolite by Asrarullah *et al.* (1979). Siddiqui and Haque (1995) mapped these rocks as Ras Koh ophiolite melange (Fig. 4).

This melange occurs as, linear, fault-bounded bodies generally within the Bunap Sedimentary complex (Fig. 4). The melange is mainly represented by partially serpentinized dunite and harzburgite with minor dismembered bodies of wehrlite, pyroxenite (diopsidite and bronzitite), gabbro, norite, basaltic-andesitic volcaniclastics, pelagic limestone, tuffaceous sandstone, amphibolite and chlorite schists. Podiform bodies of chromite and small bodies and veins of magnesite occur within the ultramafic rocks; as are small bodies and dykes of rodingide.

Siddiqui (1996) has documented a latest Paleocene to Early Eocene age for the emplacement of these bodies on the ground that these ophilitic-melenge bodies cut the Paleocene Rakhshani formation but not the Eocene Kharan limestone of Ras Koh arc. The probable age of formation of the oceanic lithosphere to which this ophiolitic-melange belongs could be Early Jurassic.

Age of the Ras Koh Accretionary Complex

The radiolarian fauna described and discussed in the foregoing pages indicates an Early to Middle Jurassic age for the lower part of the Charkohan radiolarian chert. It is inferred that the upper part of this sequence, which has intercalations of porcellaneous limestone, chert and tuff, may be of Late Jurassic to Early Cretaceous age. Two horizons of ammonite fauna are reported (Siddiqui *et al.*, 1999) within the middle tectonostratigraphic unit of the Bunap sedimentary complex, which yielded *Pachisphinctes cf. P. africanus* (Lower Kimmeridgian), *Torquatisphinctes cf. P alterniplicatus* (Upper Kimmeridgian) and *Parodontoceras cf. Blandfordiceras wallichi* (Upper Tithonian), suggesting a Late Jurassic age.

5. Conclusion

The principal finding of the present study is the discovery of the first radiolarian fauna from a sedimentary mélange unit, which was previously reported as Paleocene Rakhshani Formation by Jones (1960). This late Early to Middle Jurassic radiolarian bearing strata is named as Charkohan chert and included in Ras Koh accretionary complex. This chert sequence is considered to represents the deep marine environments before the inception of arc magmatism in the Ras Koh arc. The Late Jurassic ammonite-bearing strata (Siddiqui, 2004) of the Bunap sedimentary complex, which grade upward into the siliceous mudstone and chert with intercalations of lava flows and tuffs at the base of the Kuchakki Volcanic Group, was probably deposited on the ocean floor of the Ceno-Tethys that once occurred between the newly dislodged collage of Cimmarian continent (Central Iran, Afghan blocks, Lhasa and West Burma) and the northern passive margin of Gondwana. In these studies it is suggested that the various rock assemblage of Ras Koh accretionary complex were deposited during the Early Jurassic to Early Cretaceous and accreted with southern part of the Ras Koh arc during the Late Cretaceous to Eocene.

6. Acknowledgements

We are highly indebted to Dr. Imran Ahmad Khan, Director General, Geological Survey of Pakistan (GSP), Mr. S. Hasan Gauhar, ex-Director General, GSP and Mr. Tahir Karim Director of the same Department for their support during field and laboratory research. Prof. Shamim Ahmad Sheikh is greatly thanked for his critical review and fruitful suggestions.

References

Abdel-Gawad, M. (1971) Wrench movement in the Balochistan arc and relation to Himalayan-Indian ocean tectonics. Geol. Soc. Am. Bull., (**82**), 1235-1250.

Ahmed, M. U. (1984) Geological exploration and preliminary evaluation of Dasht-e-Kain porphyry copper-molybdenum prospect Chagai district, Balochistan, Pakistan. Ph.D. Thesis (unpublished), Univ. Belgrade, Yugoslavia.

Arthurton, R. S., G. S. Alam S. A. Ahmed and S. Iqbal (1979) Geological history of Alam Reg - Mashki Chah area, Chagai District, Balochistan. *In* A. Farah, and K. A. DeJong (eds.), Geodynamics of Pakistan. Geol. Surv. Pakistan, 325-331.

Arthurton, R. S., A. Farah and W. Ahmed (1982) The Late Cretaceous-Cenozoic history of western Balochistan, Pakistan - the northern margin of the Makran subduction complex. *In* Leggett, J. K., (ed.), Trench Fore-Arc Geology. Geol. Soc. London, Spec. Pub. (**10**), 343-385.

Asrarullah, Z. Ahmad and S. G. Abbas (1979) Ophiolites in Pakistan. *In* A. Farah, and K. A., DeJong, (eds.), Geodynamics of Pakistan, Geol. Surv. Pakistan, 181-192.

Bakr, M. A., and R. O. Jackson (1964) Geological Map of Pakistan. Geol. Surv. Pakistan, Quetta.

Britzman, L. (1979) Fission track ages of intrusives of Chagai District, Balochistan, Pakistan. M.A. Thesis (unpublished), Darmouth College, Honover, N. H., U.S.A.

Dykstra, J. D. (1978) A geological study of Chagai Hills Balochistan, Pakistan using LANDSAT digital data. Ph.D. Thesis (unpublished), Dartmouth College, Hanover, N. H., U.S.A.

Farah, A., R. D. Lawrence and K. A. DeJong (1984) An overview of the tectonics of Pakistan, *In* B. U. Haq and J. D. Milliman (eds.), Marine geology and oceanography of Arabian Sea and coastal Pakistan. Van Nostrand Reinhold Company, New York, 161-176.

Hori, R. (1990) Lower Jurassic radiolarian zone in SW Japan. Trans. Proc. Palocont. Soc. Japan, N. S. No. (**156**), 562-582.

Hunting Survey Corporation Limited, (1960) Reconnaissance Geology of Part of West Pakistan. A Colombo Plan Cooperative Project, Govt. of Canada, Toronto, Canada, 550.

Isozaki, Y. and T. Matsuda (1985) Early Jurassic radiolarian from bedded chert in Kamiaso, Mino Belt, Central Japan. Earth Science, (**38**), 429-442.

Jacob, K. H. and R. L. Quittmeyer (1979) The Makran region of Pakistan and Iran, *In* A. Farah and K. A. DeJong, (eds.), Geodynamics of Pakistan. Geol. Surv. Pakistan, 303-317.

Jones, A. G. (1960) Reconnaissance Geology of Part of West Pakistan. A Colombo Plan Cooperative Project, Govt. of Canada, Toronto, (Hunting Survey Corporation report) 550.

Kazmi, A. H. and M. Q. Jan (1997) Geology and Tectonics of Pakistan. Graphics Pulishers, Karachi, Pakistan, 554.

Kojima, S., T. Naka K. Kimura J. M. Menjal R. H. Siddiqui and M. S. Bakht (1994) Mesozoic radiolarian from the Bagh complex in Muslim Bagh area, Pakistan: Their significance in reconstructing the geological history of ophiolites along the Neo Tethys suture zone. Bull. Geol. Surv. Japan, (**45**), 63-97.

Matsuoka, A. and A. Yao (1986) A newly proposed radiolarian zonation for the Jurassic of Japan. Mar. Micro. Paleont., (**11**), 91-105.

McCormick, G. R. (1985) Preliminary Study of the Volcanic Rocks of the South Tethyan, Suture in Baluchistan, Pakistan. Acta Mineralogica. Vol. (**1**), 1-29.

McCormick, G. R. (1991) Origin of volcanics in the Tethyan zone of Pakistan. *In* Peters *et al.*, (eds.), Ophiolite Genesis and Evolution of the Oceanic Lithosphere. Ministry of Petroleum and Minerals, Sultanate of Oman, 715-722.

Naka, T., K. Kimura J. M. Mengal R. H. Siddiqui S. Kojia and Y. Sawada (1996) Mesozoic sedimentary-igneous complex, Bagh complex, in Muslim Bagh area Pakistan: Opening and closing ages of Ceno-Tethys branch. 47-94. Proceedings of Geoscience Colloquium (special issue), (**16**), 282. Jointly Published by JICA and GSP, Geoscience Laboratory Islamabad.

Nigell, R. H. (1975) Reconnaissance of the geology and ore mineralization in part of the Chagai District, Balochistan, Pakistan. U. S. Geol. Surv. Project Report (**PK-27**), 550.

Ogg, J. G., G. Ogg and F. M. Gradstein (2008) The Concise Geological Time Scale, International Commission on Stratigraphy (www.stratigraphy.org)

Siddiqui, R. H. (1996) Magmatic evolution of Chagai-Ras Koh arc terrane and its implication for porphyry copper mineralization. Geologica, (**2**), 87-119.

Siddiqui, R. H. and M. Haque (1996) Geological map of Bunap Quadrangle (unpublished), Chagai and Kharan Districts, Balochistan, Pakistan. Geol. Surv. Pak. Quetta.

Siddiqui, R. H. and M. Haque (1995) Geology and mineral occurrences of Bunap area Kharan and Chagai Districts, Balochistan, Pakistan. Geol. Surv. Pak. I. R., (**480**), 57.

Siddiqui, R. H., M. Haque and F. R. Khan (1999) First ammonite fauna from the Ras Koh arc, Balochistan, Pakistan. *In* J. Talent, F. Rabbi and R. Mason (eds.), Vol. of abstracts, First Pakistan Paleontological Convention held under UNESCO-IGCP PROJECT 421.

Siddiqui, R. H., N. Kito and M. U. Haq (1999) Middle Jurassic radiolarians from the Ras Koh arc Balochistan, Pakistan. *In* J. Talent, F. Rabbi and R. Mason (eds.), Vol. of abstracts, First Pakistan Paleontological Convention held under UNESCO-IGCP PROJECT 421.

Siddiqui, R. H. (2004) Crustal evolution of the Chagai-Ras Koh arc terrane, Balochistan, Pakistan. Unpublished Ph. D. Thesis, Centre of Excellence in Geology, University of Peshawar, Pakistan.

Sillitoe, R. H. (1974) Metallogenic evolution of a collisional mountain belt in Pakistan. Geol. Surv. Pak., Rec., **(34**), 16.

Sillitoe, R. H. (1978) Metallogenic evolution of a collision mountain belt in Pakistan: a preliminary analysis. Jour. Geol. Soc. London, (**125**), 377-387.

Spector, A. and Associates Ltd., (1981) Report on interpretation of aeromagnetic survey data, Balochistan Province, Pakistan. Project Report J-223, 107.

Stoneley, R. (1974) Evolution of a continental margin bounding a farmer southern Tethys, *In* Burk, C. I. and Drake, C. L., (eds.), The Geology of Continental Margins. Springer, New York, 873-887.

Vredenburg, W. W. (1901) A Geological sketch of Baluchistan desert and part of eastern Persia. Geol. Surv. Mem. India. 302.

Yao, A. (1986) Taxonomic studies of Lower Jurassic radiolarian from East-Central Oregon. Nat. Mus. Nat. Sci. Spec. Pub. (**2**), 1-169.