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Foraminiferal Biostratigraphy of the Sakesar Formation, Chak Naurang Well X, Potwar Sub-Basin, Upper Indus Basin, Pakistan

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ABSTRACT

The well preserved Sakesar Formation of Early Eocene in core of the Chak Naurang Well X was studied in detail for its biostratigraphy to resolve the confusion regarding the lower and upper boundaries of the unit. The target unit is 70 m thick and has conformable lower and upper contacts with the Chorgali and Patala formations respectively. Total 21 species of larger benthic foraminifera (LBF) were recorded including age diagnostic fossil i.e., Nummulites *Atacicus, Nummulites mammilatus, Nummulites globulus* with *Alveolina eliptica, Alveolina Vredenbergi* and *Sakesaria cotteri,* following modern shallow foraminiferal Larger Benthic Biozones (SBZ). Based on the erected biozones Middle Ilerdian II (SBZ 8) of Early Eocene is assigned to the deposition of Sakesar Formation. Further this study helps us in rectification of core interval that is about 55 meters which was previously logged above 70 meters.

INTRODUCTION

The Eocene rocks are very well-known major reservoirs of hydrocarbon in Kohat-Potwar Basin, Northern Pakistan and well exposed in Potwar Plateau, Salt Range, Kala Chitta, Khair-e-Murat Range and Hazara area. The Sakesar Formation is considered as one of the potential reservoir from Potwar Basin (Hasany and Saleem, 2012). Chak Naurang Well X is drilled in Chak Naurang Oil Field which is located at 32°59'38"N 72°55'32"E, central portion of Potwar Basin, District Chakwal, Punjab (Figure 1) at about 90 Km in the South-West of Islamabad.

Gee (1935, 1945) named the Formation after Sakesar Peak (Fermor, 1935) in the Salt Range later Fatmi (1973) designated as its type locality. The Sakesar Formation is mainly characterized by cream to light grey color, thick to massive bedded, having nodularity with subordinate marl and shale having chert development in topmost layer, having conformable lower and upper contacts with Patala Formation and Chorgali Formation (Shah,2009). Deposition of Sakesar Formation took place predominantly in the Northern Tethyan realm during the period of Early Eocene (Ghazi et al., 2006).

The Sakesar Formation is enriched with fossil assemblage including foraminifera, ostracods, and mollusks. Davies and Pinfold (1937) were considered as pioneers who worked on the foraminiferal biostratigraphy of the early tertiary faunal succession in the region. Gill (1953) described the occurrence of Assilina spinosa, Assilina granulosa along with some other foraminiferal species in the Sakesar Formation from the Kohat and Potwar basins, Pakistan. Boustani and Khawaja (1997) worked on microfacies analysis from the Nilawahan Gorge of Salt Range. Sameeni et al. (2010) assigned Ilerdian age of the Early Eocene to the unit based on the presence of Alveolina canavarii. Ahmad (2011) further specify the age of the Formation as Middle Ilerdian II of Early Eocene on the basis of Nummulites atacicus, Nummulites globulus, Assilina pustulosa, Assilina leymerie, Assilina granulosa, Discocyclina scalaris, Discocyclina sella and Discocyclina undulata. Ghazi et al., (2015) reported Nummulites mamillatus, N. atacicus, Assilina spinosa, A. subspinosa, A. laminosa, A. granulosa, Lockhartia tipperi, L. conditi, Discocyclina dispansa and Alveolina globula along with Orbitolites, Miliolids and Algae in Sakesar Formation of Central Salt Range, Pakistan. Rahman et al. (2017) proposed semi restricted, low energy shallow marine shelf environment of deposition based on microfacies analysis of the Sakesar Formation. Ishaq et al. (2019) worked on microfacies and diagenesis of the unit and concluding positive impact of dissolution and fracture on its reservoir characterization. The present work is mainly focused to delineate a major problem that is common in the study area (Chak Naurang) which is boundary demarcation between Sakesar Formation with younger and older Formations. For this a detailed study was carried out to identify Larger Benthic Foraminifera and establish biostratigraphic zonation for the Sakesar Formation to modify the unit boundaries in the Core of Chak Naurang well No. 4.

GEOLOGICAL SETTING

The Indian plate detached from Gondwanaland in Early Cretaceous and traveled northward about 5000 km after which collide with the Eurasian plate, resulting in the closure of Neo-Tethys Ocean to the North and opening of Indian Ocean in the South and also gave rise to a number of foreland basins, developed in India and Pakistan including Potwar Basin (Acharyya, 2007; Figure 1). Tectonically, the study area belongs to an active foreland fold and thrust belt (Salt Range/Potwar Plateau) lies in north Pakistan. The Salt Range/Potwar Plateau is basically divided into four tectonic zones i.e., Salt Range (Gee 1980), the Southern Potwar Platform Zone (SPPZ; Shami and Baig 2002), Soan Syncline and Northern Potwar Deformed Zone (NPDZ; Jaswal et al., 1997; Jadoon et al., 2008) (Figure 1). The study area (Chak Naurang oil field) lies in the SPPZ, which is bounded by Main boundary thrust (MBT) in the North and Salt range thrust (SRT) in the South while Jhelum and Kalabagh faults bound it in east and west respectively (Sethi et al., 2005; Figure 1).

The study area comprises a wide variety of structures related to the combined effects of compressional and salt tectonics (Ghazi et al., 2014). Stratigraphically, the area is characterized by thick Infra-Cambrian deposits which represent restricted evaporitic condition, overlying relatively thin stratigraphic section from Cambrian to Eocene time and thick Miocene-Pliocene molasse deposits (Khan et al., 1986). Thick Miocene-Pliocene molasses relates to severe deformation in Late Pliocene to Middle Pleistocene due to Himalayan Orogeny (Mughal et al., 2016). The stratigraphy of Chak Naurang Well X along with sample locations are 2016). The stratigraphy of Chak Naurang Well X along with sample locations are presented in Table 1.

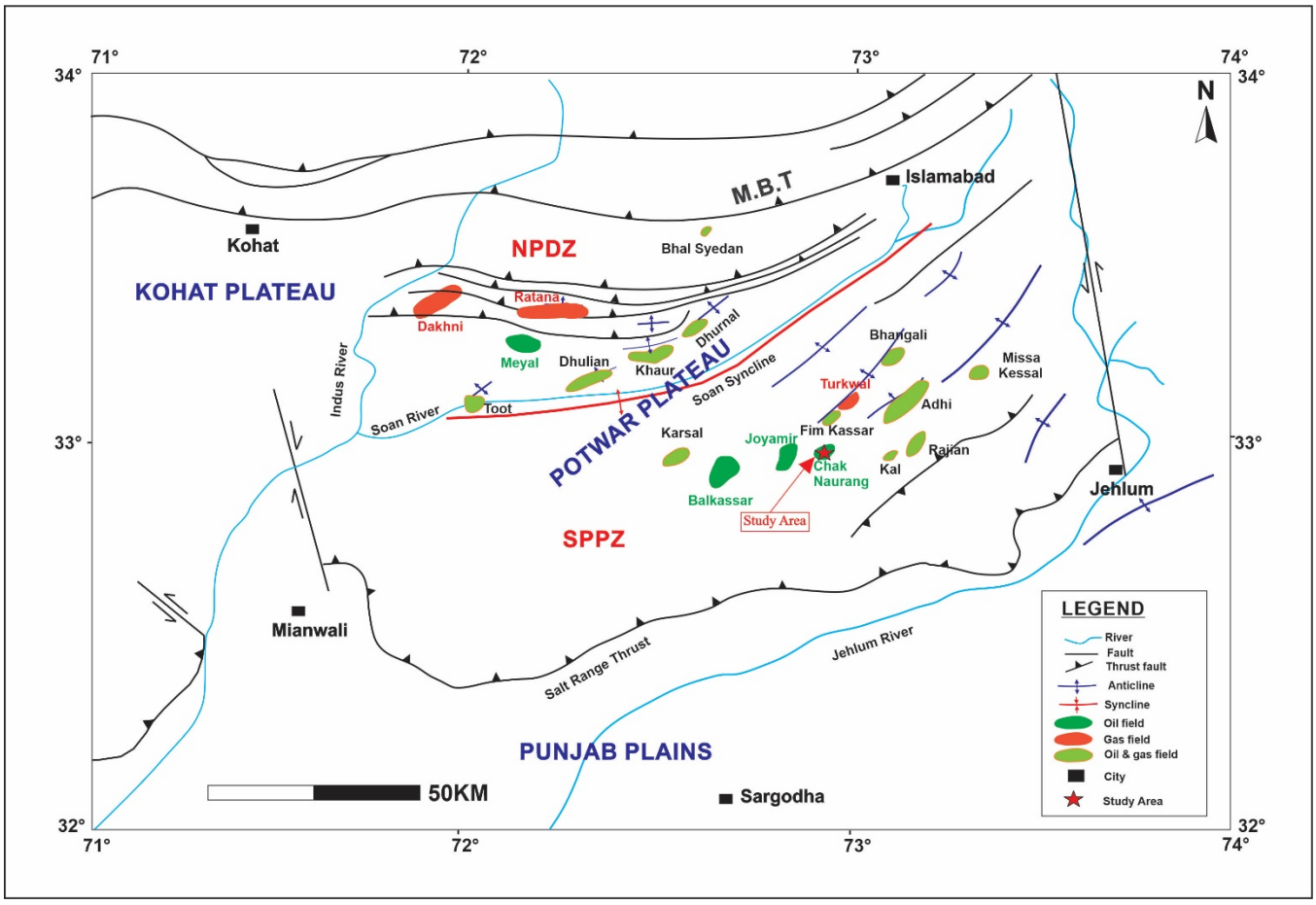
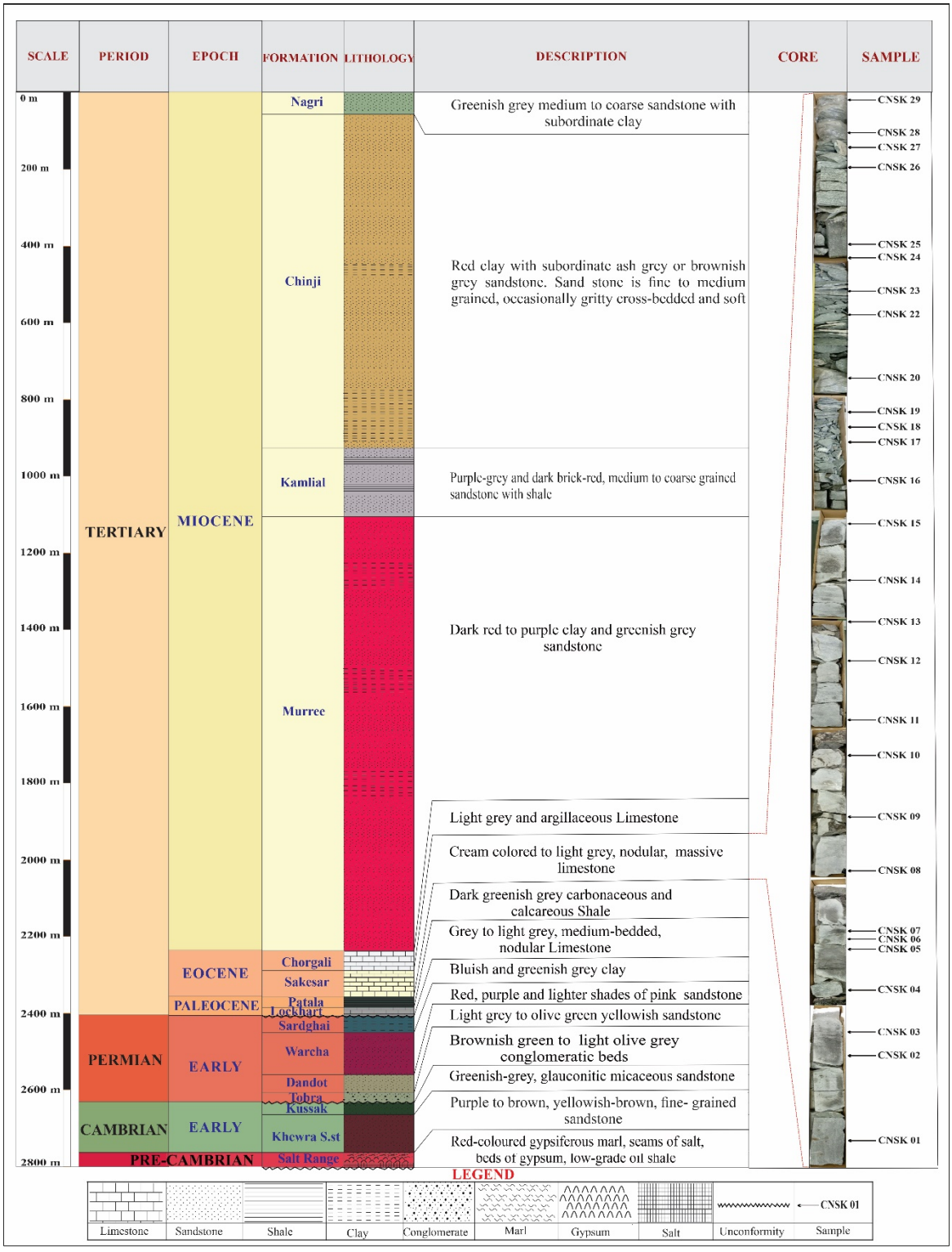


Figure 1 Tectonic Elements and hydrocarbon Fields map showing Study area (Modified after, Wandrey et al., 2004; Riaz et al., 2018, 2019)

Table 1 Stratigraphy Column of Chak Naurang Well X along with Sample location



MATERIAL AND METHODS

The samples were taken from well preserved core of Chak Naurang Well X archived at the Petroleum Core House (PETCORE), Hydrocarbon Development Institute of Pakistan (HDIP), Islamabad, using conventional methods. Samples were collected from the Sakesar Formation (mentioned in Table. 1) on the basis of faunal visibility. A total interval of 70 m was considered from 2360 m to 2290 m and 31 thin sections having dimensions 2.5 cm x 7.5 cm were prepared following standard procedure (see Green, 2013; Israni and Karlupia, 2020). Petrographic microscope (Olympus BX-51) at the sedimentology lab, Petroleum Research Department, HDIP is used for detailed petrographic studies. Shallow Benthic Foraminiferal Zonation (SBZ) scheme of Serra-Kiel et al. (1998) was followed for biostratigraphy.

RESULTS AND DISCUSSIONS

Under microscopic observations we found well oriented preserved fauna embedded in limestone. The taxa are dominantly comprised of Larger Benthic Foraminifera (LBF) with very good preservation (Figure 3). The recorded species of LBF were identified by following the morphological characteristics as proposed in classification of Loeblich and Tappan (1988) (Figure 2). Larger Benthic Foraminifera species used in this study are index taxa described for the Biozone by Serra-Kiel et al. (1998). Biozone is identified on the basis of first and last occurrence of index fossil in the studied area.

SBZ 8 (Middle Ilerdian II) is assigned to the Sakesar Formation by first appearance of *Nummulites atacicus* and *Nummulites mammilatus* other associated foraminifera that make assemblage includes *Nummulites globulus, Alveolina eliptica, Alveolina vredenbergi, Discocyclina dispensa, Assilina granulosa, Assilina subspinosa, Sakesaria cotteri, Lokhartia hunti, Lokhartia conditi, Lokhartia tipperi, Orbitolite complanatus, Miliolid sp.* and *Texularia* sp.

SBZ 8 (Middle Ilerdian II) was previously assigned by Sajjad (2011) to the Sakesar Formation on the basis LBF in Kohat Basin. In our study we also proposed SBZ 8 (Middle Ilerdian II) age to the unit based on LBF taxa.

The detailed biostratigraphic studies led us to the point that the interval assigned by the operator company was misunderstood the unit due to apparently similar nature of the lithological characteristics of Sakesar and Chorgali Formations in the core. This study also helps us in marking the boundary between Paleocene and Eocene in the Core of Chak Naurang Well X. Furthermore, this study can be used for future work in the area (Chak Naurang field) to mark Sakesar Formation interval.

CONCLUSION

The Sakesar Formation from Chak Naurang Well X, Potwar Sub-Basin is enriched with diverse larger benthonic foraminiferal assemblage. The assemblage includes stratigraphically significant taxa proposing SBZ-8 (Middle Ilerdian II) of the Early Eocene to the Sakesar Formation on the basis of first occurrence of *Nummulites Atacicus, Nummulites mammilatus* along with association of *Nummulites globulus, Alveolina eliptica, Alveolina Vredenbergi, Assilina granulosa, Assilina granulosa, Sakesaria cotteri* and *Orbitolite complanatus.*

Based on our biostratigraphic studies we come up with the conclusion that the actual core interval of Sakesar Formation is about 55 meters thick and the record of PETCORE, HDIP was corrected in which the unit was logged above 70 meters.

Table 2 List of recorded Larger Benthic Foraminifera of Chak Naurang Well X

Nummulites mammilatus (FICHTEL & MOLL), Fig. 3 (1)
Nummulites atacicus LEYMERIE 1846, Fig. 3 (2)
Nummulites globulus LEYMERIE 1846, Fig. 3 (3)
Lokhartia conditi NUTTALL 1926, Fig. 3 (5)
Lokhartia hunti OVEY 1947, Fig. 3 (6)
Lokhartia tipperi DAVIES 1926 Fig. 3 (4)
Assilina laminosa GILL 1953 Fig. 3 (7)
Assilina granulosa d'ARCHIAC 1850, Fig. 3 (9)
Assilina subspinosa DAVIES 1937, Fig. 3 (8)
Alveolina eliptica SOWERBY 1840, Fig. 3 (10)
Alveolina vredenbergi DAVIES 1937, Fig. 3 (12)
Alveolina globula HOTTINGER 1960, Fig. 3 (11)
Discocyclina dispensa SOWERBY, 1840, Fig. 3 (13)
Orbitolite complanatus LAMARCK, 1801, Fig. 3 (16)
Sakesaria cotteri DAVIES, 1937, Fig. 3 (18)
Quinqueloculina d'ORBIGNY 1826 Fig. 3 (22)
Orbitolite sp., Fig. 3 (17)
Discocyclina sp., Fig. 3 (14)
Bigenerina sp., Fig. 3 (13, 14)
Ranikhothalia sp., Fig. 3 (17)
Nodosaria sp., Fig. 3 (18)
Miliolid sp., Fig. 3 (23)
Texularia sp., Fig. 3 (24

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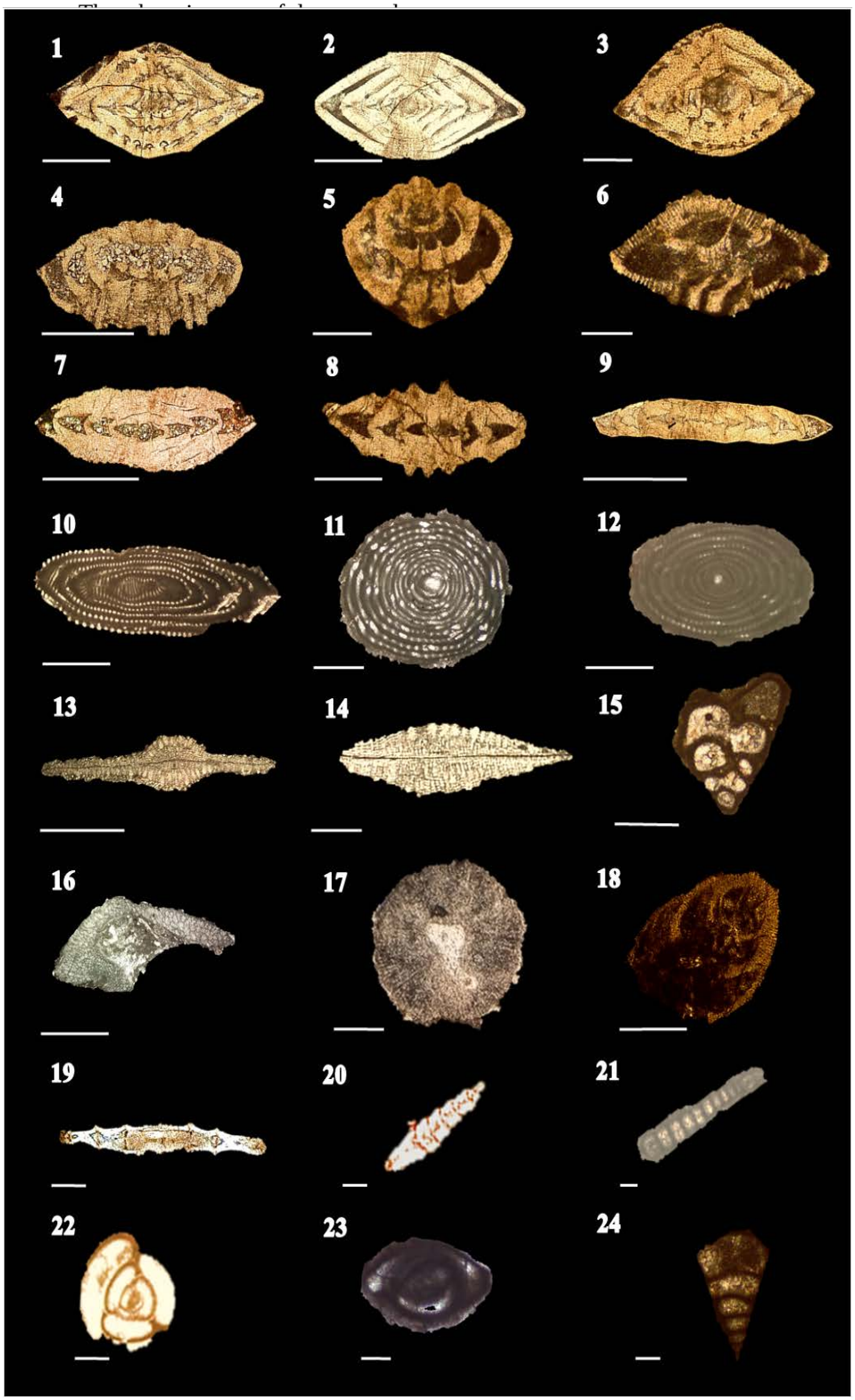

Figure 2 Photomicrograph of LBF of Sakesar Formation. 1. Nummulites atacicus, 2. Nummulites mammilatus, 3. Nummulites globosa, 4. Lokhartia tipperi, 5. Lokhartia conditi, 6. Lokhartia hunti, 7. Assilina laminosa, 8. Assilina subspinosa, 9. Assilina granulosa, 10, 11. Alveolina globula, 12. Alveolina vredenbergi, 13. Discocyclina dispensa, 14. Discocyclina sp., 15 Bregeneria sp., 16. Orbitolite complanatus, 17. Orbitolite sp., 18. Sakesaria cotteri, 19. Ranikhothalia sp., 20, 21. Nodosaria sp., 22. Quinqueloculina, 23. Miliolid sp., 24. Texularia sp

parts of the Sakesar Formation based on biostratigraphic investigations helps in accurately demarcating the boundary between Paleocene and Eocene in the Core of Chak Naurang Well X as well as correcting the total thickness of the Formation. The study will help the geoscientists for future work in other wells of Chak Naurang Field in identifying Sakesar Formation on the basis of current findings.

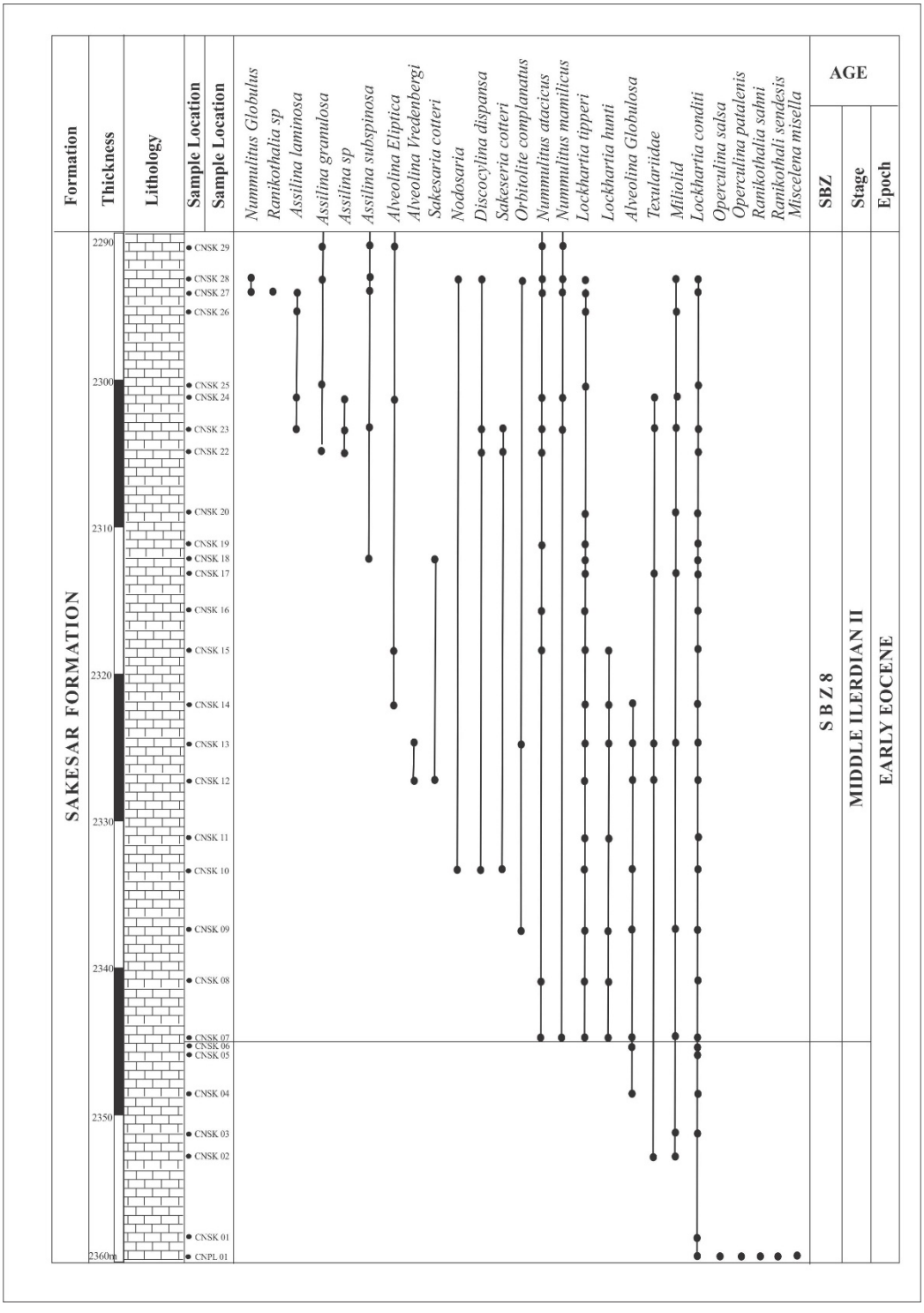

Figure 3 Biostratigraphic column and specimen stratigraphic range of LBF of Chak Naurang well X

REFERENCES

Acharyya, S. K. (2007). Evolution of the Himalayan Paleogene foreland basin, influence of its litho-packet on the formation of thrust-related domes and windows in the Eastern Himalayas–A review. *Journal of Asian Earth Sciences*, *31*(1), 1-17.

Ahmad, S. (2011). *Paleogene larger benthic foraminiferal stratigraphy and facies distribution: implications for tectonostratigraphic evolution of the Kohat Basin, Potwar Basin and the Trans Indus Ranges (TIR) northwest Pakistan* (Doctoral dissertation, University of Edinburgh).

Boustani, M., & Khawaja, A. M. (1997). Microfacies studies of the Sakesar Limestone Central Salt Range, Pakistan. *Geol Bull Univ Peshawar*, *30*, 131-142.

d Archiac, E. J. A. (1850). Description des fossiles du group Nummulitique recueillis par MSP Pratt et M. Delbos aux environs de Bayonne et de Dax. *Memoires de la Societe Geologigue de France*, *3*, 397-456.

Davies, L. M., & Pinfold, E. S. (1937). The Eocene beds of the Punjab, Salt Range: Mem. Geol. Surv. India, Pal. Indica. *New Ser*, *24*(1), 1-79.

Fatmi, A. N. (1973). Lithostratigraphic units of the Kohat-Potwar Provine Indus Basin, Pakistan.,(3), 22-28. *Geological Survey of Pakistan*, *10*.

Fermor, L. L. (1935). General report of the Geological Survey of India for the year 1934. *Records of the Geological Survey of India*, *69*(1), 1-108.

Fichtel. L.V.; Moll, J. P. C. (1798). *Testacea microscopia, aliaque minuta ex generibus Argonauta et Nautilus, ad naturam delineata et descripta. A. Pichler*, Wien. 12 (123) 24

Gee ER (1980) Salt Range series geological maps: *Directorate of Overseas Surveys, United Kingdom, for Government of Pakistan and Pakistan Geological Survey*, 1: 50,000, 6 sheets

Ghazi, S., A. A. But, and M. Asharf (2006). Microfacies analysis and diagenesis of the Lower Eocene Sakesar Limestone, Nilawahan Gorge, Central Salt Range, Pakistan. *J. Nepal Geol. Soc*., 33: 23-32.

Ghazi, S., Ali, S.H., Sahraeyan, M. and Hanif, T., (2014). An overview of tectonosedimentary framework of the Salt Range, northwestern Himalayan fold and thrust belt, *Pakistan. Arabian Journal of Geosciences*, 8(3), 1635-1651

Ghazi, S., Sharif, S., Hanif, T., Ahmad, S., Aziz, T., & Riaz, M. (2015). Micropalaeontological analysis of the early eocene sakesar limestone, central salt range, pakistan. *Pakistan Journal of Science*, *67*(2), 150.

Gill, W. D. (1953). Facies and fauna in the Bhadrar beds of the Punjab Salt Range, Pakistan. *Journal of Paleontology*, 824-844.

Green, O. R. (2013). *A manual of practical laboratory and field techniques in palaeobiology*. Springer Science & Business Media.

Hasany, S. T., & Saleem, U. (2012). An integrated subsurface geological and engineering study of Meyal Field, Potwar Plateau, Pakistan. *Search and Discovery Article*, *20151*, 1-41.

Hottinger, L. (1960). Recherches sur les Alvéolines du Paléocène et de l'Éocène. *Mémoires Suisses de Paléontologie, Basel*. 1-243.

Ishaq, M., Jan, I. U., Hanif, M., & Awais, M. (2019). Microfacies and diagenetic studies of the early Eocene Sakesar Limestone, Potwar Plateau, Pakistan: approach of reservoir evaluation using outcrop analogue. *Carbonates and Evaporites*, *34*(3), 623-656.

Israni, R., & Karlupia, S. K. (2020). The Study of Rocks in Thin Section under Polarizing Microscope. *Sustainable Humanosphere*, 16(1), 1437-1442

Jadoon IAK, Frisch W, Jadoon MSK (2008) Structural traps and hydrocarbon exploration in the Salt Range/Potwar Plateau, North Pakistan. In: SPE *Annual Technical Conference, Islamabad*, pp 69–83.

Jaswal TM, Lillie RJ, Lawrence RD (1997) Structure and Evolution of the Northern Potwar Deformed Zone, Pakistan. *AAPG Bull* 81:308–328

Khan, M. A., Ahmed, R., Raza, H. A., & Kemal, A. (1986). Geology of petroleum in Kohat-Potwar depression, Pakistan. AAPG Bulletin, *70*(4), 396-414.

Leymerie, A. (1846). *Mémoire sur le terrain à Nummulites (Epicrétacé) des Corbières et de la Montagne Noire* 1 (8). P. Bertrand.

Loeblich, A.R. & Tappan, H. 1988. *Foraminiferal Genera and their Classification*. Van Nostrand Reinhold, New York, 1-1728.

Mughal, M. S., Zhang, C., Du, D., Zhang, L., Mustafa, S., Hameed, F., ... & Blaise, D. (2018). Petrography and provenance of the Early Miocene Murree Formation, Himalayan Foreland Basin, Muzaffarabad, Pakistan. *Journal of Asian Earth Sciences*, *162*, 25-40.

Nuttall, W. L. F. (1926). The larger foraminifera of the Upper Ranikot Series (Lower Eocene) of Sind, India. Geological *Magazine*, *63*(3), 112-121.

Ovey, C. (1947). A new Eocene Species of Lockhartia Davies, from British Somaliland, with Notes on other Species of the Genus. *Annals and Magazine of Natural History*. 13(104), 571-576.

Rahman, Z., Muhammad Khan, Z., Khattak, Z., Abbas, M. A., & Ishfaque, M. (2017). Microfacies Analysis and Resrvoir Potential of Sakesar Limestone, Nammal Gorge (Western Salt Range), Upper Indus Basin, Pakistan. *Pakistan Journal of Geology (PJG)*, *1*(1), 12-17.

Riaz, M., Pimentel, N., Ghazi, S., Zafar, T., Alam, A., Ariser, S. (2018). Lithostratigraphic Analysis of the Eocene reservoir units of Meyal area, Potwar Basin, Pakistan. *Himalayan Geology*, 39(2): 161-170

Riaz, M., Pimentel, N., Zafar, T., Ghazi, S. (2019). 2D Seismic Interpretation of Meyal area, Northern Potwar Deform Zone (NPDZ), Potwar Sub-Basin, Pakistan. *Open Geosciences*, 11: 1-16.

Sameeni, S. J., Imtiaz, R., Saleem, H., Malik, Z., Ali, S., Haneef, M., & Mirza, K. (2010). Biostratigraphy of Sakesar limestone, Rikhi-Burikhel area, Western Salt Range, Pakistan. *Journal of Himalayan Earth Sciences*, *43*, 77-77.

Serra-Kiel, J., Hottinger, L., Caus, E., Drobne, K., Ferrandez, C., Jauhri, A. K., & Zakrevskaya, E. (1998). Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. *Bulletin de la Société géologique de France*, *169*(2), 281-299.

Sethi, K. W., Mujtaba, G., Mahmood, H., Khan, W. A., & Alam, I. (2005). Delineation of regional tectonics of north eastern Potwar by using gravitational methods. In *Society of Petroleum Engineers/Pakistan Chapter and Pakistan Association of Petroleum Geoscientists (SPE/PAPG) Annual Technical Conference, Islamabad*.

Shah, S. M. I. (2009). *Stratigraphy of Pakistan*. Published by the Geological Survey of Pakistan. 22, 247.

Shami BA, Baig MS (2002) Geomodelling for the enhancement of hydrocarbon potential of Joya Mair Oil Field, Potwar, *Pakistan SPE/PAPG Annual Technical conference*, Islamabad, pp 124-145

Tappan, H., & Loeblich Jr, A. R. (1988). Foraminiferal evolution, diversification, and extinction. *Journal of Paleontology*, 695-714.

Wandrey et al., 2004