REVISED STRATIGRAPHY OF SARGODHA-CHINIOT AREA PUNJAB, PAKISTAN

BY

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Abstract: *The northern part of the Punjab plains is punctuated by isolated hillock type exposures of Kirana complex consisting of Proterozoic volcano-sedimentary sequence. The Kirana complex was conventionally divided into two main series including volcanic and metasedimentary on basis of field data and geological mapping. The present appraisal deals with the revised stratigraphy of Kirana complex on the basis of new field, mapping, and subsurface data. In present study, the rocks of Kirana Hills are divided into Hachi volcanic Group and Machh super Group. The underlying Hachi volcanic group is further divided into Wad Syyidan Formation and Buland Hill Formation. The Machh super Group is comprised of Kirana Group and Sharaban Group. The underlying Kirana Group consists of three units including Chalk 112 Conglomerates, Tuguwali Formation and Asianwala Formation whereas the overlying Sharaban Group is comprised of Hadda Formation and Chak 102 Conglomerate. The sequence is unconformably overlain by Late Proterozoic to Cambrian Salt Range Formation.*

INTRODUCTION

The upper Proterozoic outcrops of the Kirana isolated hills cutting out of flat Punjab alluvial plain lie between 72° 37' 30" and 72° 47' 30" E longitudes and 31° 50' 50" to 31° 59' 00" latitude N. The Chiniot outcrops occur between longitudes 72° 54' 24" and 72° 59' 00" E and latitudes 31° 43' 18" and 31° 46' 11" N. The outcrop near Shahkot town has been consumed and relief is negative whereas a small remnant survives near Sangla Hill. (Fig. 1)

The igneous component of these rocks and their equivalents in Tusham (Haryana Province India) and Kirana Hills (Pakistan) are the remnants of bimodal igneous activity within the Malani Basin (Kochhar 1984, 1998, 1999, 2000; Kochhar et al., 1991, 1994: Eby and Kochhar 1990; Bushan and Chittora, 1999) designated as Kirana Malani Basin by Chaudhry et al., (1999). These upper Proterozoic rocks are composed of rift related bimodal volcanics and volcaniclastics overlain by low grade coarsening upwards meta-sediments. Ahmed (1964) also regarded Kirana exposures as part of Precambrian basement. Farah et al., (1977) carried out extensive gravity studies and concluded that rocks exposed in Pakistan in Kirana (Punjab) and Nagar Parker (Sindh) are components of a NW-SE buried ridge of the "Indian Shield". Moreover, the exposures in Punjab were fault bound steep horst complexes. Based on interpretations of magnetic data, Dolan et. al., (1987) regarded Kirana (Pakistan) and Tusham and Rajasthan exposures (India) as a part of a NW-SE buried ridge of Indian Shield. Kazmi and Jan (1997) also considered Kirana rocks as a part of the Indian Shield.

Chaudhry et. al., (1999), Ahmad and Chaudhry (2008, 2009) and Khan et. al., (2009) carried out extensive studies in the area and concluded that Kirana igneous and metasedimentary rocks cannot be correlated with rocks of the Vindhyan Basin of India and therefore are not a part of the Aravalli Orogen which is a part of the Indian Shield. Instead, they belong to a rift related tectono-magmatic upper proterozoic bimodal volcanic, hypabyssal and clastic meta sedimentary sequence. Davis and Crawford (1971) dated the igneous activity between 850 Ma to 750 Ma. The igneous activity may be linked with the breakup of Rodina Supercontinent and opening of Mozambique Basin due to the rising of Mantle Plume (Chaudhry et. al., 1999).

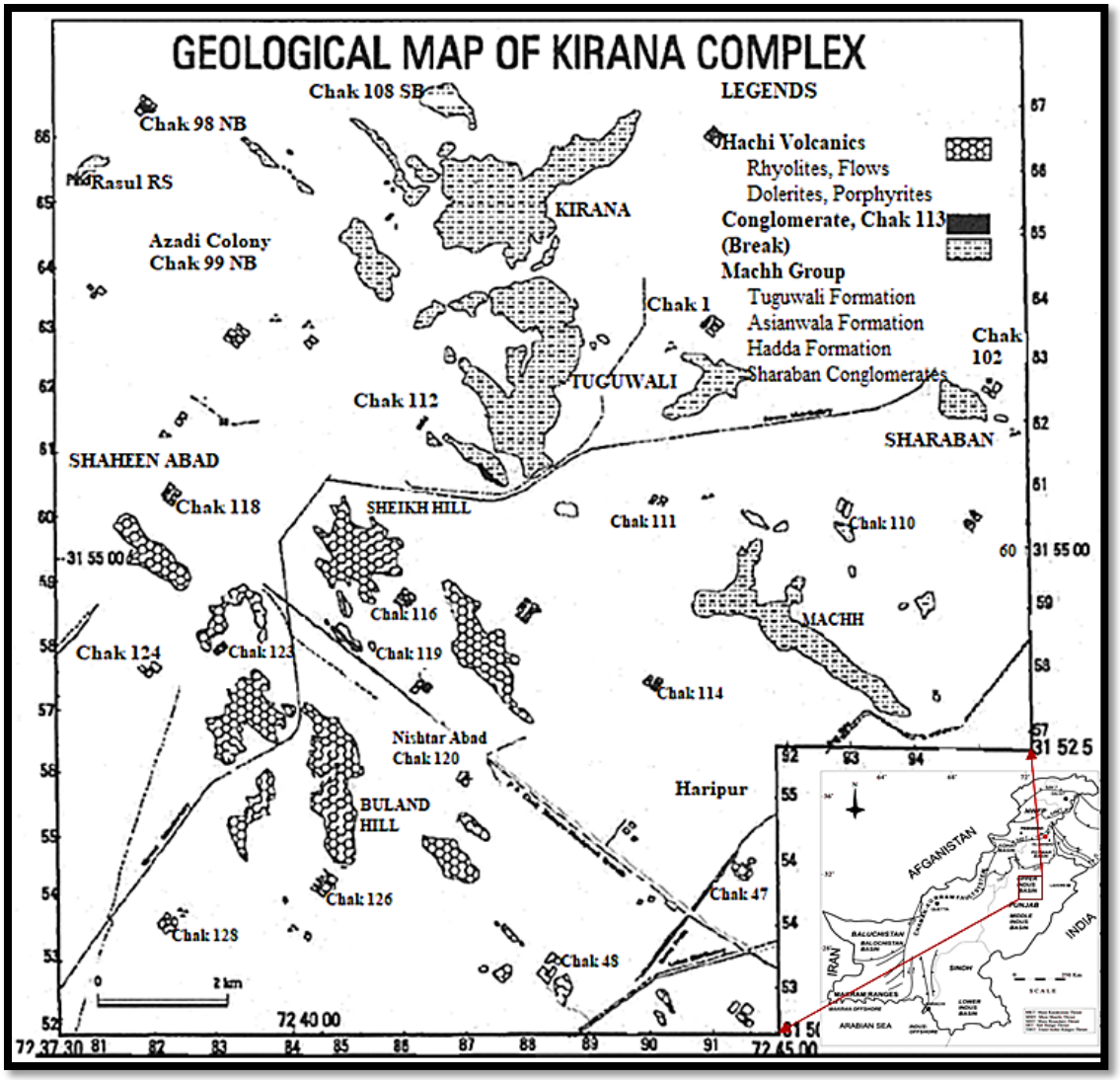

Fig. 1 Geological map of Kirana Complex [modified after Khan (2000) and Khan et al., (2009)]

The Kirana-Milani complex (Chaudhry et. al., 1999) is probably the largest felsic volcanic field in the world. The geological information on Malani igneous suits in India, over the past decades, is available in the work of Kochhar (1984, 1998, 1999, 2000), Kochhar et al., (1991, 1994) Bushan and Chittora (1999) and Ghosh et. al., (2022).

STRATIGRAPHY

Heron (1913) of Geological Survey of India was the pioneer who studied and described the geology as well as worked out stratigraphic super-position of the outcrops of Kirana area. He divided the sequence into five formations and the nomenclature is still being used.

These formations are:

- Sharaban Formation
- Hadda Formation
- Asianwala Formation
- Tuguwali Formation
- Hachi Formation

Later on, Shah (1973, 1977) adopted the same nomenclature. Alam (1987) mapped the area, carried out petrographic studies and aggregated Heron's (1913) formations into two groups namely Kirana Group and Sharaban Group. His stratigraphic scheme is given as Table 1.

Table 1: Stratigraphic Classification of Kirana Hills (After Alam, 1987)

Group	Formation	Description
Sharaban Group	Sharaban Conglomerate	Conglomerate, dull rusty brown containing pebbles of quartzite, slate, and limestone embedded in calcareous matrix. Its thickness is 199m.
	Hadda Quartzite	Quartzite is dull rusty brown, fine grained, calcareous, and typical of shallow marine origin or deltaic, containing minor conglomerate beds and rare lava flows. Its thickness is 372 m.
Kirana Group	Asianwala Quartzite	Quartzites, light grey to dirty white, mottled brown, medium to coarse grained, cross bedded, ripple marked and contains minor conglomerates of slate. Its thickness is 248 m.
	Tuguwali Phyllite	Phyllite, light grey, minor conglomerates of quartzites. Lower part is fine-grained and quartzite is cross-bedded. Its thickness is 1190 m.
	Hachi Volcanics	Hachi Volcanics composed of slates, minor quartzites with abundant tuff and lava flow of acidic composition. Its thickness is 404 m.

Chaudhry et al., (1999) proposed a modified stratigraphic scheme based on the following observations.

1. The Hachi volcanics and metadolerites constitute a distinct bimodal lithostratigraphic unit and its base is not exposed while the top is unconformable. The distinct unconformity is well marked by Chak 112 conglomerate (Chaudhry, 1999; Khan, 2000). It is 2 meters thick polymictic conglomerate with clasts of the underlying dolerites and rhyolites.
2. It is a distinct entity comprised of slightly metamorphosed (lower green schists facies) acid volcanics tuffs and ashes as well as Meta dolerite sills and dykes. This unit can be correlated with Tusham-Malani volcanics of India.
3. The overlaying metasedimentary units represent an overall coarsening upwards sequence.
4. There is a distinct and a clear-cut break between the Hachi Volcanics and the overlying meta-sediments (marked by Chak 112 conglomerates).

Alam (1987) and Alam et. al., (1992) reported that package of Sharaban Hills contained volcanic material. According to Chaudhry et al., (1999) “the two packages i.e. the lower predominantly volcanic package and the upper meta sedimentary sequence were formed in two distinct petro-tectonic environments and represent two distinct petro-tectonic assemblages. Neither the base of Sharaban Group is exposed nor its top preserved anywhere. Since there are only two small exposures of this unit in Sharaban Hill, therefore giving it the status of a distinct group is not justified.

Table 2: Stratigraphic Classification of Kirana Hills (Chaudhry et al., 1999)

Group	Formation	Description
Machh Super Group	Sharaban Formation	Conglomerates with slate intercalations
	Hadda Formation	Calcareous quartiztes
	Asianwala Formation	Mainly quartzites with subordinate quartz wackes/arenaceous slates, gritty quartzites and slates, often showing cross bedding and ripple marks
	Tuguwali Formation	Slates, fine grained quartz wackes/arenaceous slates
	Chak 112 Conglomerates	Polymictic conglomerate with clasts of dolerite and acid volcanics

Hachi Volcanics	Volcanogenic slates	Often interbedded with rhyolite/ rhyolitic tuff and dolerite
	Volcanics	Dolerites, andesites, dacites, dacitic tuff, rhyolites and rhyolitic tuff

In the light of new information gathered from the bore holes, especially from Wad Sayyidan, Gutti Sayyidan and Chak Jhumra the stratigraphy of Chaudhry et al., (1990) has been modified by (Hartsch et al., 2018), Table 3.

Table 3: Stratigraphic Classification of Kirana Hills (Hartsch et al., 2018)

Group	Age	Formation	Description
	Cambrian	Salt Range Formation	The Salt Range Formation consists of mudstones, siltstones, sandstones and dolomite with intercalations of gypsum. Its thickness is 80 m
	Unconformity Salt Range Formation in Chak Jhumra overlies unconformably on Hachi Group		
Machh Super Group	Proterozoic	Sharaban Formation	Conglomerates with intercalations of slate. Its thickness is 190 m
	Proterozoic	Hadda Formation	Calcareous quartzites. Its thickness is 350 m
	Proterozoic	Asianwala Formation	Mainly quartzites with subordinate quartz wackes/arenaceous slates, gritty quartzites and slates. It often shows cross bedding and ripple marks. Its thickness is 250 m.
	Proterozoic	Tuguwali Formation	Slates, fine grained quartz wackes/arenaceous slates. Its thickness is 1210 m.
	Proterozoic	Chak 112 Conglomerates	Polymictic conglomerate with clasts of dolerite and acid volcanics. Its thickness is 3 m.
Hachi Volcanic Group	Proterozoic	Buland Hill Formation	Volcanogenic slates. Often interbedded with rhyolite/rhyolitic tuff and dolerite. In addition, it contains dolerites, andesites, dacites, dacitic tuff, rhyolites and rhyolitic tuff. Its thickness is 390 m Base not encountered
	Proterozoic	Wad Sayyidan Formation	Volcanics and volcanic clastics, inter bedded with slates, graphitic slates, dolomites and quartzwackes. Its thickness is 1054 m Base did not encounter.

However according to Shah (2009), Chaudhry et al., (1999) coined the term "Machh Super Group" to correlate rocks of Kirana area to the similar rocks of "Marwar Super Group" of India. They included all the formations of Alam (1987) except Hachi Volcanics and the name Kirana Group and yet they named no Group of any kind to go along with their Super Group. This according to Shah (2009) was against the Stratigraphic Code of Pakistan." Therefore, a review was proposed which is acceptable. In this review Hachi Group and Kirana Group are being retained to conform to the practice of the Stratigraphic Committee of Pakistan.

Furthermore, according to Shah (2009) "Admittedly Machh Super Group of Chaudhry et al., (1999) fits very well in correlation with Marwar Super Group of India." Considering Shah (2009) and Hartsch et al.,

(2018), a new stratigraphic Table 4 has been given in the following as the latest stratigraphic set up in Kirana area.

Table 4: Revised Stratigraphic Classification of Kirana Hills

Super Group	Group	Age	Formation	Description
		Late Proterozoic to Cambrian	Salt Range Formation	The Salt Range Formation consists of mudstones, siltstones, sandstones and dolomite with intercalations of gypsum. Its thickness is 80 m.
Unconformity, the Salt Range Formation in Chak Jhumra overlies unconformably on Hachi Group				
Machh Super Group	Sharaban Group	Proterozoic	Chak 102 Conglomerate	Conglomerates with slate intercalations. Its thickness is 190 m.
		Proterozoic	Hadda Quartzite	Calcareous quartzites. Its thickness is 350 m.
	Kirana Group	Proterozoic	Asianwala Formation	Quartzites with subordinate quartz wackes/arenaceous slates, gritty quartzites and slates, often showing cross bedding and ripple marks. Its thickness is 250 m.
		Proterozoic	Taguwali Formation	Phyllite and subphyllite with subordinate quartz wackes/arenaceous slates. Its thickness is 1210 m.
		Proterozoic	Chak 112 Conglomerates	Polymictic conglomerate with clasts of dolerite and acid volcanics. Its thickness is 2 m.
	Hachi Volcanic Group	Proterozoic	Buland Hill Formation	Felsic volcanics and volcanogenic slates, often interbedded with rhyolite, rhyolitic tuff, andesites, dacites and dacitic tuff, swarm of dolerite sills and some dykes, intrude volcanics and volcaniclastics. Its thickness is 390 m. Base not encountered.
		Proterozoic	Wad Sayyidan Formation	Mafic volcanics and volcaniclastics inter bedded with slates, graphitic slates, dolomites and quartzwackes. Its thickness is 1054 m. Base did not encounter.

DESCRIPTION OF ROCK TYPES

Hachi Volcanic Group

The Hachi Volcanic Group is mainly comprised of thick sequence of volcanics and volcaniclastic rocks. The volcanics are dominantly acidic to intermediate in composition and mainly include rhyolite, rhyolitic tuff, andesite, dacite and dacitic tuff. The volcanics and volcaniclastic rocks are interbedded slates, graphitic, dolomite, quartz wacke and volcanogenic slates. The swarms of dolerite sills and dolerite dykes also occur at places which having intrusive contact with volcanogenic slates and volcanics with chilled margins. The Hachi volcanic Group is further subdivided into Wad Sayyidan Formation which is overlain by Buland Hill Formation.

Wad Sayyidan Formation: This unit is found in Wad Sayyidan and Gutti Sayyidan areas of Chinot District. It mainly consists of volcanics and volcaniclasts interbedded with slates, graphitic slates, dolomite and quartzwacke. Volcanics are predominantly mafic in composition and mainly include basalts and basaltic

andesite whereas the volcaniclastic rocks mainly composed of volcanipyroclastics with some agglomerates. Volcanics are generally fine to medium grained. The volcanics and vocaniclasts are interbedded with slates, graphitic slates, dolomite and quartzwacke. The slates and graphitic slates are generally dark grey to blackish grey and fine grained. The maximum thickness of this unit is recorded about 1054m. Its base is not exposed whereas it is unconformably overlain by subrecent to recent sediments of Punjab Plain (Hartsch et al., 2018).

Buland Hill Formation: This unit is widely exposed in Buland Hill, Hachi Hill, Tuguwali, Kirana Hill, Shaheenabad, Chak 123, Chak 118, Chak 128 and Chak 126. It is mainly comprised of volcanics and volcanogenic slates. The Buland Hill volcanics are predominantly acidic in composition consisting of rhyolites with some dacite and andesites. Volcanics are often interbedded in volcanogenic slates and vice versa. Often, these occur as alternate bands with dolerite dykes/sills as at Shaheenabd, Hachi and Shaikh Hill. Volcanics are generally fine grained rarely subporphyritic with glassy to microcrystalline matrix. Rhyolitic and dacitic tuff also occur at places. The volcanic and volcanogenic slates are often intruded by swarms of dolerite sills and dykes. The maximum thickness of this unit is estimated about 390m and it is unconformably overlain by rocks of Machh Super Group.

Dolerite Dykes: Dolerites are generally black to green in color and well exposed at Hachi, Shaheenabad and Hachi hills. They are auto-metasomatic and subsequently metamorphosed to lower greenschist facies. These rocks are fine to medium grained and often blastoporphyritic but hypidioblastic texture may also be encountered. Plagioclase is generally andesine or labradorite. Plagioclase may show variable alteration to epidote and calcite. It varies from 20 to 45 %. Like plagioclase, chlorite is an essential mineral most probably formed after pyroxene and amphibole. It imparts a green color to the rock. It varies from 20 to 53 %. Calcite varies from an accessory (4.5 %) to an essential mineral (20 %). Amphibole, quartz, ilmenite, magnetite, hydromica orthoclase epidote and sphene occur as accessories. Occasionally epidote may be an essential mineral (10 %). However, rarely dolerites may be unmetasomatised and may be composed of plagioclase (labradorite), pyroxene, olivine and accessories like sphene, quartz, K-feldspar and magnetite. While rhyolites and equivalent volcanic and volcanoclastics are dominant, dacite and rare andesite is a minor accomplice. The main constituent of these rocks are variably reconstituted to glassy to cryptocrystalline matter (39 – 51 %), quartz (12 – 22 %), K-feldspar (5 – 16 %), albite/ oligoclase (3 – 17 %) whereas magnetite, hematite/limonite, epidote, muscovite, chlorite and zircon occur as accessories. For detailed geochemistry of the volcanic rocks of Kirana Hills, Punjab, Pakistan the reader is referred to Ahmad and Chaudhry (2008, 2009).

Machh Super Group

The metasedimentary package of Machh Super Group unconformably overlies the Buland Hill Formation of Hachi volcanic Group. The metasedimentary package starts with a polymictic conglomerate comprising of clasts of underlying volcanics and volcaniclastics of Hachi Volcanic Group. The overlaying Machh Super Group is composed of Kirana Group and the Sharaban Group.

Kirana Group

The Kirana Group is mainly comprised of thick sequence of metasediments including slates, quartzite and quartzwackes with minor conglomerates at its basal part. It is further subdivided into three rock units including Chak 112 conglomerate, Taguwali Formation and Asianwala Formation, from bottom to top respectively.

Chak 112 Conglomerate: It is mainly composed of polymictic conglomerate. The conglomerate consists of clasts of volcanics, volcanogenic rocks and dolerite derived from rocks of the underlying Hachi volcanic Group. Rhyolite and dolerite are the major constituent sof conglomerate. The clasts are generally subrounded to subangular. The maximum thickness of unit is about 3m. The upper and lower contact of unit with Taguwali and Buland Hill formations are both unconformable.

Taguwali Formation: The Taguwali Formation consists predominantly of subphyllites, phyllites and subordinate Meta quartz wackes and Meta greywackes. The phyllites and subphyllites are

composed predominantly of phyllosilicates with subordinate quartz, chert and at places, minor volcanic material. The accessories are hematite, limonite, epidote, zircon and rare tourmaline. The quartzite is generally fine grained and thin bedded with occasional thick beds. The meta-quartz wackes and meta-greywackes are rich in matrix composed of phyllosilicates and tiny grains of quartz. These rocks are un-equigranular to subequigranular and composed of metasandstone lithoclasts, chert and phyllosilicates with chlorite, calcite, iron oxides, feldspar, epidote, zircon and tourmaline as accessories. The maximum thickness of Taguwali Formation is recorded about 1210m and it has upper conformable contact with overlying Asianwala Formation.

Asianwala Formation: It is dominantly comprised of quartzwacke/lithic greywackes with subordinate phyllite and subphyllites which occur as intercalations. Quartzite is gritty at places and often shows cross bedding and ripple marks. Quartzite is dirty white to light grey and brown. It is thick bedded, coarse grained pebbly at places (Alam, 1987). Asianwala quartzite is similar to Taguwali quartzite. Both have, more or less, the same mineralogy and are dominated by quartzwackes and lithic greywackes. The two formations together constitute a coarsening upwards package. These units may contain intra-formational flat pebble conglomerates and specularite hematite veins and encrustations at places. The thickness of unit is estimated about 250m and it has upper contact with alluvium at type locality (Alam, 1987).

Sharaban Group

The Sharaban Group is mainly composed of calcareous quartzite and conglomerates with minor slates and lava flows. It is well exposed in Sharaban Hill area and has been divided into two units namely Hadda Formation and Chak 102 conglomerate. The petrographic composition and characteristics of Sharaban Group have not been studied in detail.

Hadda quartzite: It is mainly comprised of calcareous quartzite with minor slates, conglomerate and lava flow. Quartzite is fine grained and thick to very thick bedded. It is frequently rusty brown to dull rusty brown and light grey to brownish grey at surface. Alam (1987) reported contorted layering and slump structures in this unit. The lava flows are generally greenish grey and occur within quartzite beds Shah (2009). Conglomerates are mainly comprised of flat pebbles of quartzite, dolerite and slate with minor vein quartz, jasper and limestone and they frequently occur in the upper part of the unit (Shah, 2009). The total thickness of this unit is about 350m. Its lower contact is concealed at type locality whereas the upper contact is gradational with Chak 102 conglomerate.

Chak 102 Conglomerate: It is mainly comprised of conglomerate with minor intercalations of slates. Conglomerates are generally rusty brown to dull rusty brown and are classified as polymict. These are mainly composed of pebbles of quartzite, slate, dolerite and minor limestone and red jasper derived from the underlying rocks. The matrix of conglomerates is frequently calcareous. Quartzite and slate constitute the dominant fraction of pebbles. Limestone pebbles are generally grey and unfossiliferous. The conglomerates are intercalated with dark grey to blackish grey slates at places. The maximum thickness of Chak 102 conglomerate is 190m and its upper contact is with subrecent to recent sediments of Punjab Plain.

According to Hartsch et al (2018) “The Salt Range Formation unconformably overlies the Hachi volcanics in a borehole in Gutti Sayyedian. This formation is composed of siltstone, mudstone, sandstone and marble” and placed it in Cambrian. However, in present account the Salt Range Formation has been placed at Late Proterozoic to Cambrian because Mazumdar and Bhattacharta (2004) regarded both carbonates (Bilara dolomite) and evaporite sequence (Hanseran evaporites equivalent of Salt Range Formation in western India) in lower to middle part of Marwar Super Group as coeval facies on the basis of stable isotope data and variation in lithology and assigned Late Neoproterozoic to early Cambrian age.

CONCLUSIONS

The present appraisal suggests a revised nomenclature for stratigraphic units of Kirana and Chinot areas of Pakistan on basis of new information and geological data. According to this revised stratigraphic set up, the Proterozoic sequence of Sargodha and Chinot districts (Kirana Complex) is divided into Basal Hachi volcanic Group which is unconformably overlain by

metasedimentary package of Machh super Group. The Hachi Volcanic Group is further subdivided into Wad Sayyidan and Buland Hill formations whereas the overlying Machh super Group is divided into Kirana and Sharaban groups. The Kirana Group is comprised of Chak 112 conglomerate, Taguwali and Asianwala formations while overlying Sharaban Group consists of Hadda Formation and Chak 102 Conglomerate.

REFERENCES

Ahmad, S. A., and Chaudhry, M. N. (2008). Kirana Volcanics, Pakistan-Geochemical Characterization and Origin. *Geol Bull Punjab Univ*, *43*, 49-57.

Ahmad, S. A., and Chaudhry, M. N. (2009). Crystallization history of the kirana volcanics, Sargodha, Pakistan. *Geol Bull Punjab Univ*, *44*, 1-9.

Alam, G. S. (1987). Geology of Kirana Hills District Sargodha, Punjab 1, Pakistan. *GSP Quetta, 201*, 1-37.

Alam, G. S., Jaleel, A. and Ahmad, R. (1992). Geology of the Kirana area, District Sargodha Punjab, Pakistan. *Acta Mineralogica Pakistanica*, *6*, 93-100.

Bhushan, S. K., & Chittora, V. K. (1999). Late Proterozoic bimodal volcanic assemblage of Siwana subsidence structure, western Rajasthan, India. *Journal-Geological Society of India*, *53*, 433-452.

Chaudhry, M. N., Ahmad, S. A., & Mateen, A. (1999). Some postulates on the tectonomagmatism, tectonostratigraphy and economic potential of Kirana-Malani-Basin, Indo-Pakistan. *Pakistan Journal of Hydrocarbon Research*, *11*, 52-68.

Davies, R. G. Crawford. AR, (1971). Petrography and age of the rocks of Buland hills, Sargodha Districts West Pakistan. *Geological Magazine*, *108*, 235-246.

Dolan, P. Edgar, D. C. B. and Sherlin, B. J. (1987). Pakistan regional geology and petroleum exploration potential. Dolan and Associates. Non-Exclusive Report. London.

Eby, G. N., & Kochhar, N. (1990). Geochemistry and petrogenesis of the Malani igneous suite, North Peninsular India. *J. Geol. Soc. India*, *36*(2), 109-130.

Farah, A., Mirza, M. A., Ahmad, M. A., & Butt, M. H. (1977). Gravity field of the buried shield in the Punjab Plain, Pakistan. *Geological Society of America Bulletin*, *88*(8), 1147-1155.

Ghosh, S., D'Souza, J., B.R., Prabhakar, N., (2022). A review of the Precambrian tectonic evolution of the Aravalli Craton, northwestern India: Structural, metamorphic and geochronological perspectives from the basement complexes and supracrustal sequences. Earth-Science Reviews.

Hartsch, J., Zernke, Helbig, M., and Kutzke, A. (2018). Prospecting at the Adjoining Areas of Wad Sayyidan, Ghutti Sayyidan and Chak Jhumra, and Regional Geology of the Kirana Basement High, Punjab, Pakistan. PMC Final Report. Vol. 1, N1 43-101 Report pp. 240.

Heron, A. M. (1913). the Kirana and other hills in the Jeeb and Rachna Doabs, Memoirs, G.S.I, records, *43*, 229-236.

Kazmi, A. H. and Jan, M. Q. (1997). *Geology and Tectonics of Pakistan*. Graphic Publishers, Karachi, Pakistan.

Khan, Z. K. (2000). *Study of the geology of Kirana Group, central Punjab and evaluation of its utilization and economic potential as aggregate* (doctoral dissertation, university of the Punjab, Lahore, Pakistan).

Khan, Z. K., Ahsan, N., Mateen, A., & Chaudhry, M. N. (2009). Petrography and mineralogy of dolerites of Hachi Volcanics, Kirana Hills Area, Pakistan. *Geol. Bull. Punjab Univ*, *44*, 55-67.

Kochhar, N. (1984). Malani Igneous Suite: Hot-spot magmatism and cratonization of the Northern part of the Indian shield. *Journal of Geological Society of India*, Vol. No. *25*(3), 155-161.

Kochhar, N. (1998). Malani igneous suite of rocks. *Journal of Geological Society of India*, 51(1), 120-120.

Kochhar, N. (1999). A comparative study of the Malani representatives of the Tusham Hills (Haryana, India) and Kirana Hills (Pakistan). Proceedings of 3rd South Asia Geological Congress, Lahore, Pakistan

Kochhar, N. (2000). Attributes and significance of the A - Type Malani Magmatism, Northwestern Pensiular India. In M.Deb (Ed), Crustal evolution and Metallogeny in the Northwestern Indian Shield. Chapter 9, pp. 158-188, New Delhi, 525.

Kochhar, N., Dhar, S., & Sharma, R. (1995). Geochemistry and tectonic significance of acid and basic dykes associated with Jalor magmatism, west Rajasthan. *Mem. Geol. Soc. India*, *33*, 375-389.

Kochhar, N., Vallinayagam, G., & Gupta, L. N. (1991). Zircons from the granitic rocks of the Malani igneous suite: morphological and chemical studies. *Journal of Geological Society of India*, 38(6), 561-576.

Mazumdar, A., and Bhattacharya, S.K., (2004). Stable isotopic study of late Neoproterozoic-Early Cambrian (?) sediments from Nagaur-Ganganagar Basin, western India: Possible signatures of global and regional C-isotopic events. Geochem. J. *38*, 163–175

Shah, S. M. I. (1973). Occurrence of Gold in the Kirana Group, Sargodha (Punjab) Pakistan. Inform Release, GSP, Quetta, Pakistan: *68*, 1-14.

Shah, S. M. I. (1977). Stratigraphy of Pakistan. *Memoirs of the Geological Survey of Pakistan, 12*, 1-38.