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Some Postulates on the Tectonomagmatism, Tectonostratigraphy and Economic Potential of Kirana - Malani Basin: Implications for Occurrence of Petroleum

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ABSTRACT

The so called shield elements exposed to the west of the Aravalli Orogen and exposed in Kirana, Nagar Parkar, Jodhpur, Malani, Tosham, Mount Abu and Erinpura are neither a part of Aravalli Orogen nor do they belong to the Vindhyan Basin. These volcanoplutonic and sedimentary rocks represent a distinct cratonic rift assemblage. They were deposited in extensional basins formed as a result of rising of the mantle plume around 1000 ma. This basin is named by us as Malani-Kirana Basin. The stratigraphy of Kirana area has been revised and correlated with the Indian counterpart areas west of the Aravalli range. The Hachi volcanics are correlated with Tosham volcanics. The later are a part of an extensive volcanoplutonic igneous province with other centres in Rajasthan and Nagar Parkar. The overlying sedimentary package of Kirana area is designated by us as Machh Super Group and it includes Tuguwali formation, Asianwala quartzites. Hadda quartzites and Sharaban conglomerates.

The Machh Super Group is correlated with the lower part of the Marwar Supergroup. The equivalents of the upper Marwar Super Group must occur in Pakistan to the south and south west of Kirana adjoining Bikaner - Nagaur Basin of India. Metamorphism in the Machh Super Group sediments must decrease in this direction, therefore hydrocarbon prospects may occur in Pakistani region adjoining hydrocarbon bearing Bikaner - Nagaur Basin of India.

Volcanic hosted massive oxide-sulfide deposits have recently been discovered in the subsurface in Hachi volcanics near Chiniot. Such deposits must exist throughout Kirana-Malani Basin west of the Aravalli Orogen.

INTRODUCTION

Kirana Hills of Sargodha - Shahkot - Sangla - Chiniot area are a few exposures of the Precambrian rocks in upper Punjab. The exposures are a part of many hillocks west of Aravalli range and are spread over a vast area both in India and Pakistan. Since similar exposures also occur in Nagar Parkar area, it appears that the Indus Basin is underlain by these crystalline rocks with or without Phanerozoic cover. These rocks are exposed as an isolated outcrops jutting out of the alluvium of the Indus Plain. In Sargodha they are spread over an area of 90 sq.km. The outcrop area is covered by Toposheets No. 44 A/9 and 41 A/3 and lies between longitudes 72° 38' 48" to 72° 48' and latitudes 31° 51' to 32° 15' (Figure 1). The area has assumed importance because of the discovery of volcanic hosted massive oxide sulfide deposit in the subsurface near Chiniot.

The geology of Kirana-Molani Basin is shown in figure 2.

PREVIOUS WORK

Heron (1913) was the first geologist who presented the preliminary geological observations and carried out a reconnaissance geological survey of the Sargodha area. He considered the Kirana complex as the extension of Indian Shield representing Vindhyan Basin. He also considered these rocks as part of the Aravalli mountain system of India and listed the following lithologies.

i) Shales and slates
ii) Quartzites
iii) Tuffs and rhyolites
iv) Basic rocks

Davies and Crawford (1971) presented petrographic and geochronological studies based on a few samples of Buland Hill area. They identified the rock units as acid volcanic rocks among which are intercalated some thin bands of sedimentary origin as well as minor amounts of basic lava and tuff. Intruded into this pile is one fairly large lense of acid igneous material situated on the south-west flank of Buland Hill and a number of concordant or semi-concordant sheets or sills of doleritic compositions.

A few very narrow dykes of dolerites are also seen cutting the volcanic pile. The field relationship shows that these basic intrusives postdate all of the acid igneous rocks and that their position of emplacement has been controlled by the presence of thin intercalations of fissile or tuffaceous sediments in the volcanic package.

Davies and Crawford (1971) also determined Rb-Sr age of 870±40ma for these rocks.

Shah (1973) gave a preliminary description of Kirana group and indicated anomalous values of gold in diabases from the main Kirana outcrop. He subdivided the rocks exposed into following five formations.

i. Sharaban Formation

Conglomerates, dull rusty brown, containing pebbles of quartzites, slate and limestone, embedded in calcareous matrix.

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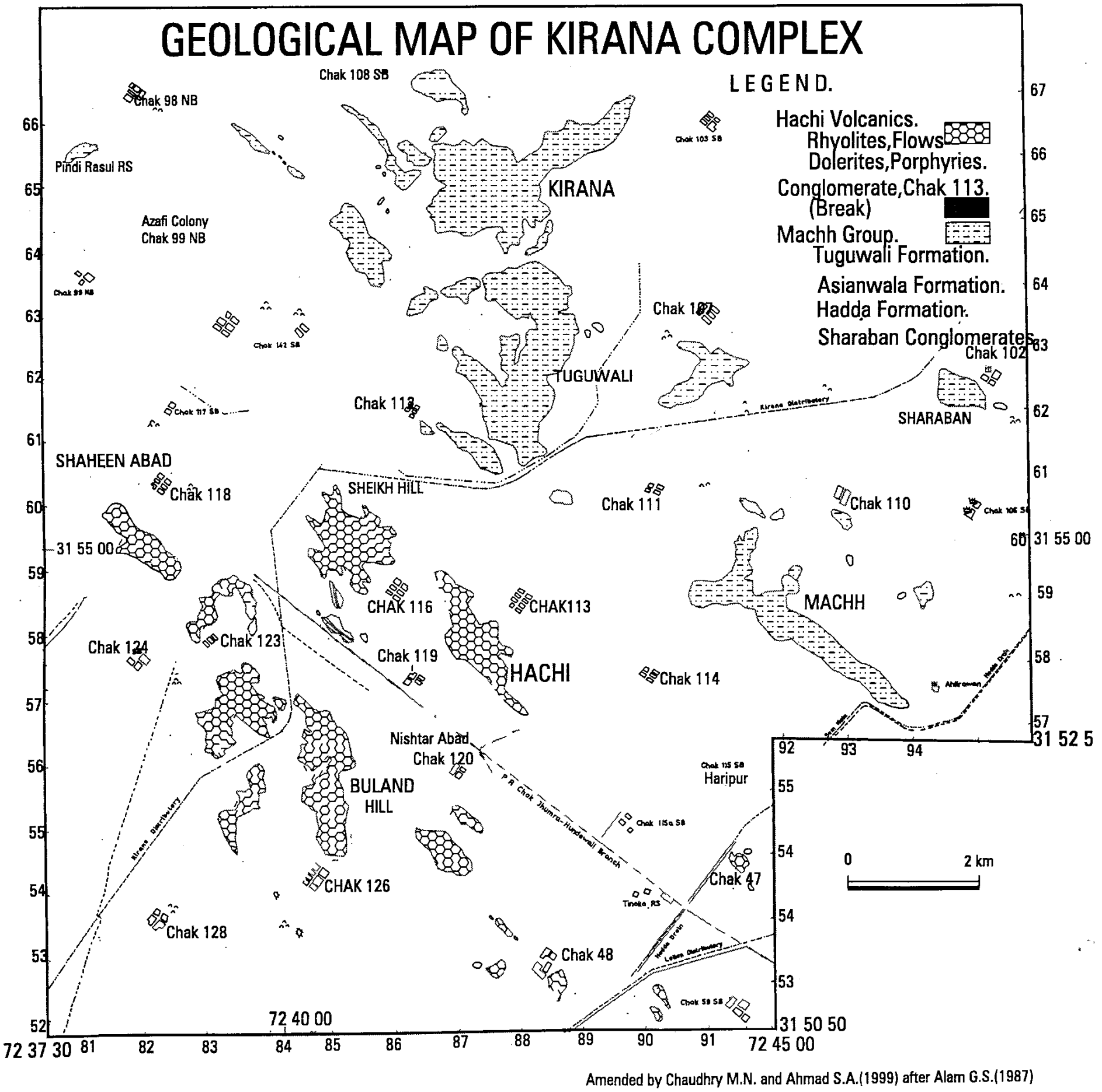

Amended by Chaudhry M.N. and Ahmad S.A.(1999) after Alam G.S.(1987)

Figure 1- Geological map of Kirana Basin (Modified after Alam, 1987).

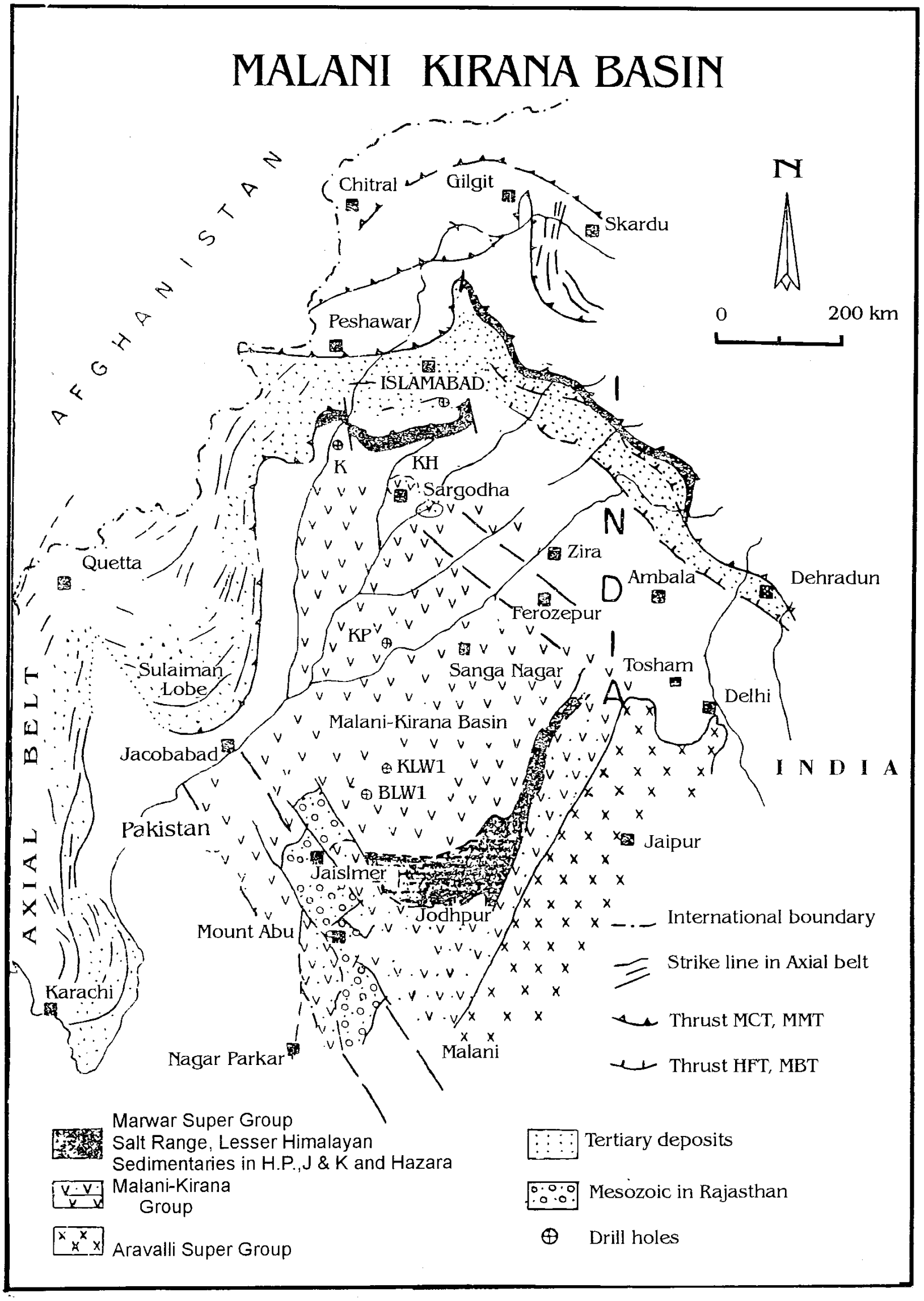

Figure 2- Outline geological map of northern and western India and Pakistan (Modified after Virdi, 1997).
(KH=Kirana Hills, KP=Karampur, K=Kundian, D=Dhariala, NJR=Nagar Park Jacobabad Ridge, DSR= Delhi- Sangodha Ridge)

ii. Hadda Formation

Quartzites, dull rusty brown, fine grained, calcareous, typical of shallow marine or deltaic origin, containing minor conglomerate beds and rare lava flows.

iii. Asianwala Formation

Quartzites, light grey to dirty white, mottled brown, medium to coarse grained, cross bedded, ripple marked and containing minor intercalations of slate.

iv. Tuguwali Formation

Phyllite with light grey minor intercalations of quartzites. Lower part comprises fine grained quartzites, cross bedded, slates, minor quartzites with abundant tuffs and lava flows.

v. Hachi Formation

Quartzites, slates, phyllites, tuffs and lava flows. He considered Buland hill rocks (Hachi formations) as synchronous with the rocks of the Vindhyan System.

Alam (1987) modified the stratigraphy of the area as follows:-

Sharaban Group	Sharaban Conglomerates Hadda quartzites
Kirana Group	Asianwala Quartzites *Tuguwali Phyllites* Hachhi Volcanics

He listed the lithologies as slates, phyllites, tuffs, lava flows, quartzites and sills of dolerite.

Dolan et al. (1987) presented magnetic and gravity data interpreting continuity of Kirana and Nagar Parkar bodies with shield complexes of Indian elements which according *to them belong to the Aravalli system.*

Farah et al. (1979) considered the Kirana outliers as the surface projections of a buried "Sargodha Ridge" extending north-westward from Indian Shield whereas south-eastern extension is believed to join the Hisar Ridge, west of Delhi, India. A similar situation has also been proposed for Nagar Parkar outliers as projections of a buried ridge that extends in N.W. direction. Structurally, Kirana and Nagar Parkar outliers are considered as horst like bodies with steeply faulted contacts, nearly vertical strata and variable strike directions.

Gansser (1964) showed divergent N.E. trend in eastern hills and N.W. trend in the western hills of Kirana, the former extends towards the Aravalli range to N.W. India and the later trend matches the Himalayan Range in the north.

Ahmad (1964) considered these ridges belonging to a system of "Swells" in the Precambrian basement that were responsible for the existence of various sedimentary basins.

According to Seeber and Armbruster (1979) the "Sargodha Ridge" is seismically active and belongs to the Punjab Seismic Zone that includes the Hisar Ridge and extends to Delhi, India (Manke and Jacob 1976). Exploratory wells drilled at Kundian (31°00N; 74° 17'E) and at Karampur (29° 53' N 72° 21' E), north and south of Sargodha Ridge respectively show a complete stratigraphic similarity and prove post-sedimentation emplacement by tectonism of the ridge.

Yeats and Lawrence (1984) explained the tectonic configuration of the Sargodha Ridge as outer "Swells" that had risen as a result of stresses generated by loading of Indian Shield by the Himalayan thrust sheets.

Discussing the geotectonic events in the Trans-Aravalli region, Virdi (1997) regarded the Kirana-Nagar Parkar complexes as "Malanis" part of Aravallis.

Muslim et al. (1997) thought that Nagar Parkar complex is similar to those of adjoining Indian Shield rock complexes.

Butt et al. (1992) considered the Nagar Parker rocks as similar to Erinpura granitic complex of Malanis as well as Mount Abu as part of Aravallis.

Moreover they proposed these rocks to be products of crustal anataxis in an intraplate (continental) anorogenic environment.

GEOLOGY

The oldest rocks exposed in Kirana area are volcanics and volcaniclastics. These are composed predominently of *rhyolite flows and rhyolitic tuffs, whereas andesites and* dacites are minor. The volcanic sequence contains interbeds of slates, which have been considered in the past as metasediments but are at least in part volcanogenic in origin (Khan and Chaudhry 1991). The second important group of rocks are the doleritic sills which postdate the acid volcanics. The volcanism is bimodal in nature. These *volcanics are unconformably overlain by a sequence of* phyllites which in turn are overlain by quartzites. The unconformity is represented by polymictic conglomerates (Khan unpublished work). The clasts are well rounded and are composed of dolerites, acid volcanics and volcaniclastics. We designate this conglomerate as Chak No. 112 conglomerate.

The overlying phyllites have been named as Tuguwali phyllites (Alam 1987). This unit is 1190 m thick (Alam 1987) *and is composed of phyllites and quartzite. Many of the horizons described by Alam as quartzites are in fact quartz* wackes. This sequence appears to be turbiditic in nature. Tuguwali phyllites are overlain by Asianwala Quartzite. The top of the Asianwala Quartzite is not exposed. It is comprised of quartzites, gritty quartzites and metawackes. It is often crossbedded and ripple marked. Hadda quartzites and conglomerates are exposed in Sharaban and Chandar hills. Hadda quartzite is composed of calcareous quartzites, with minor conglomerate horizons.

Sharaban conglomerates are 119m thick. The top is however not preserved. This unit is composed of dull rusty brown conglomerates with intercalations of slate. Nowhere is the contact between Tuguwali phyllites and Hadda quartzites exposed.

STRATIGRAPHY

Rocks of Kirana area have been divided by Alam (1987) into two groups i.e. Kirana group and Sharaban group. The Kirana group which is considered older is divided into three units as follows:-

3) Asianwala Quartzites
2) Tuguwali Phyllites
1) Hachi Volcanics

The Sharaban group has been divided by him into lower 1) Hadda quartzites and an upper 2) Sharaban conglomerate.

This division needs revision because of the following reasons:-

i) The Hachi volcanics constitute a very distinct lithostratigraphic unit. Its base is not exposed and the top is unconformable. The unconformity is marked by a polymict conglomerate designated by the present authors as Chak No.112 conglomerate.

ii) It is a separate and distinct entity with bimodal volcanism. It is correlatable with Tosham-Malani volcanics.

iii) The overlying sedimentary package has a distinct history and represents a coarsening upward sequence. No significant volcanic activity is seen in this sedimentary package. There is hardly any doleritic sill or dyke in the sequence.

There is a distinct time gap between the Hachi volcanics and the overlying metasediments.

The two packages i.e. the lower pre-dominantly volcanic package and the upper sedimentary sequence were formed in two distinct petrotectonic environments and represent two distinct petrotectonic 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 and Chandar hills, therefore giving it the status of a distinct group, is not justified.

In view of the above a modified stratigraphic framework is proposed which is given in table 1.

DISCUSSION

The Kirana complex lies to the west of the Aravalli range. The Aravalli orogeny has been dated as 2000 ma (Gopalan 1984) whereas the closing of the Delhi orogeny which resulted in giving the Aravalli range its final configuration has been dated between 1500 to 1700 ma (by Choudhary et al., 1984) and 1650 to 1700 ma by Crawford and Compston (1970). In fact, the Aravalli and Delhi orogenies are a single continuous Proterozoic orogenic cycle which included collision of the Proterozoic cratons, the shields and their representative shallow platform sedimentary cover. This ultimately resulted in the formation of Proterozoic super continent that was broken twice during subsequent geologic history (Condie, 1981). The release of stresses of the Aravalli orogen and its counter clockwise movement resulted in extension to the west and marginal compression to the east. It is also believed that, in the post Aravalli period at about 1000 ma. rifting started in the Indo-Gangetic area. This was due to Mantle plume which resulted in widespread igneous activity in Rajasthan, Haryana and Kirana areas. Extension of the crust not only resulted in widespread volcanism and plutonism but also the subsequent deposition of sedimentary package of Marwar Supergroup in India and Machh Supergroup in Pakistan. The Hot spot activity due to which widespread volcanism and plutonism took place appears to have started at around 1000 ma. The centres of these activities were Tosham 940±20 (Kochhar, 1974) 754±20 ma (Kochhar, 1984), Kirana (873±40 870±40), Nagar Parkar (800-750) (Davies and Crawford, 1971) and Malani 745±40 (Crawford and Compston 1970). Siwana and Jalore at 750 ± 14 ma (Rathore et al., 1991).

The igneous activity appears to have died down after Malani episode and sedimentation started afterwards. The extensional tectonics generally results in wide variations in

Table 1. Stratigraphic nomenclature of the area.

----------Top not preserved ----------	
Machh Super Group	a) Sharaban fm (conglomerates with slate intercalations) b) Hadda formation (Calcareous quartzites). c) Asianwala formation (Mainly quartzite with subordinate quartzwackes, gritty quartzites and slates. It is often ripple marked and crossbedded). d) Tuguwali formation (slates, fine grained quartz wackes). e) Chak 112 conglomerates (polymict conglomerate clasts of dolerite and acid volcanics).
Hachi volcanics	(Rhyolite, rhyolitic tuff, dacite, dacite tuff, andesite, andesite tuff, minor slates, dolerite sills).
----------Base is not exposed----------	

Correlation with Marwar Group

Kirana Complex	**Marwar Complex**
Machh Super Group	**Marwar Super Group**
Top Not Exposed	-
?	Bilara Formation (cherty dolomite, Limestone and ferrugenious breccia
Sharaban conglomerate	-
Hadda quartzite	-
Asianwala Formation	Jodhpur Formation
Tuguwali Formation	Sonia Formation
Chak 112 conglomerate	Basal Formation
Hachi Volcanics	**Tosham - Malani Volcanics**

the type of volcanic activity and formation of peraluminous, peralkaline as well as Tholeiitic rocks. The Aravalli orogen, on the other hand, was formed as a result of the collision of various shield elements. The volcanic activity to the west which started about 1000 ma was due to extensional movements and thinning of the crust resulting in the formation of a number of rifts.

The Vindhyan basin lies to the east of the Aravalli orogen and was under compressional regime due to the counter clockwise movement of the Aravallis. This basin terminates at G.B.F. (Great Boundary Fault). We therefore propose the name Kirana-Malani basin for the extensional basin complex to the west of the Aravalli range. The stratigraphy of the Kirana area (Pakistan) has been revised and correlated with the stratigraphy of comparable rocks in India (Table 1). On the basis of geochronological data the Hachi volcanics are correlated with Tosham volcanics in Haryana. Lower part of the Marwar Supergroup has been correlated with the newly designated Machh Super Group of Kirana area, Pakistan. The Salt Range formation of Cambrian age overlies the Kirana basement rocks. This has been confirmed in boreholes at Karampur well and at Kundian. Nowhere the rocks of Machh Super Group overlie the Salt Range or younger formations. The rocks of the Machh Super Group are therefore older than Cambrian. These rocks have also undergone lower greenschist facies metamorphism which could have happened in Pan-African Orogeny. These rocks are of Upper Proterozoic age but younger than the Hachhi volcanics of 870±40 ma (Davies and Crowford 1971). Therefore, the age of this Super Group lies between 870 ± ma to 570 ma. These rocks are lithologically similar to the rocks of Hazara group of Latif (1970). We therefore propose the correlation of Tuguwali and Asianwala formations with Hazara Attock Slates. The rocks in Kirana area are believed to be a part of Vindhyan basin (Heron 1913, Shah, 1973). This is not correct because Vindhyan basin lies to the east of Aravalli range. The basin to the west of this range where volcanoplutonic activity as well as sedimentation took place in an extensional setting is named here as Kirana - Malani basin.

ECONOMIC GEOLOGY

Hydrocarbons

Ahmed (1998) while analysing the hydrocarbon potential of the Central Indus Basin has discussed the hydrocarbon potential of Bikaner - Nagaur Basin as well. Heavy oil has been discovered in Jodhpur and Bilara Formations of early Cambrian-Infracambrian below the salt beds and asphaltic crude oil has been found in upper carbonate formation (Late Cambrian). The Bikaner - Naugaur Basin must continue westward into Pakistan. We have correlated the Asianwala quartzite with Jodhpur sandstone and Tuguwali phyllites with Sonia Shales. The later formations to the south and south west of Kirana, if buried under younger sediments, may also contain hydrocarbons.

Massive Volcanics Hosted Oxide Sulfide Deposits

Recently massive volcanic hosted oxide-sulfide deposits have been found in the subsurface near Chiniot at a depth of about 70 to 150 meters. These deposits are comprised of an upper massive haematite zone underlain by magnetite and sulfide horizons. These deposits were most probably formed under the sea due to submarine volcanism and convection currents. The interbedding of the ore beds with volcanic intervals represents multiple volcanic eruptions each followed by a quiet period. The deposit is hosted by rhyolitic tuffs which erupted under the sea.

CONCLUSIONS

1. Kirana-Tosham-Malani-Nagar Parkar volcanoplutonic and sedimentary packages belong neither to Aravalli range nor to the Vindhyan basin.
2. The entire area lying to the west of Aravalli range is a distinct basin named by us as Kirana - Malani basin.
3. The Hachhi volcanism can be correlated with Tosham volcanics of Haryana which are a part of wider igneous province with other volcanic centres in Rajasthan and Nagar Parkar.
4. There is a distinct unconformity between Hachi Formation and the overlying sedimentary package.
5. The Machh Super Group can be correlated with lower part of the Marwar Super Group.
6. The rocks (Kirana-Malani) lying to the west of Aravalli Orogen do not represent a basement but a basin which is only slightly deformed and either totally unmetamorphosed or metamorphosed in lower greenschist facies only.

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