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Scientific Research

Provenance, Tectonics and Paleoclimate of Permo-Carboniferous Talchir Formation in Son-Mahanadi Basin, Central India with Special Reference to Chirimiri: Using Petrographical Interpretation

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ABSTRACT

The present study deals with the petrographic interpretation of Talchir Formation sandstone, in and around Chirimiri area, Koriya district, Chhattisgarh state India located in Son-Mahanadi basin. This basin is an elongate graben showing northwest-southeast trend and considered to be one of the largest intra-cratonic rift basins of Indian peninsula. Talchir Formation is the lowermost unit of thick classical Gondwana sedimentary succession and rests unconformably on Precambrian basement. The petrographic studies consisting of point count show the presence of quartz as a dominant framework mineral with subordinate amounts of feldspars and rock fragments. The data plot in the fields of cratonic interior and transitional margin of continental block provenance. In the Qt (quartz)-F (feldspar)-L (lithic fragments) triangular diagram, indicating the source of these sediments was located in transitional margin and continental block provenance. The petrographic classification suggests that this formation in the study area dominantly contains compositionally immature to submature arkosic, sub-arkosic and lithic-arkosic sandstones. The bivariate plot between Qp/(F+R) vs. Qt/(F+R) indicates changes in climatic conditions from semi-arid to semi-humid during Permo-Carboniferous period.

KEYWORDS

Son-Mahanadi; Talchir Formation; Chirimiri; Provenance; Tectonics; Petrography; Paleoclimate

1. Introduction

The compositions of sandstone have been widely used by sedimentologists during past several decades to decipher the provenance, paleoclimate and tectonic setting of the source areas [1-9]. The characters of detrital framework grains are substantially affected by the nature of processes that act in the depositional basin and also by the type of transporting medium and distance of transport [8,10]. Determination of different aspects of provenance viz its location with respect to depositional basin, lithology, climate and tectonic setting is some of the important parameters of basin analysis [11].

The Gondwana sediments of Peninsular India mark the resumption of sedimentation during Permo-Carboniferous after a long hiatus since Proterozoic. The sedimentation in Gondwana basins of India evolved through a complex interplay of faulting, changes in sea level and climate [12]. The basinal geometry was modified by tectonic movement during different periods. Indian plate is an assembly of several micro continents, sutured along early/middle Proterozoic Mobile belts [13-15]. These mobile belts became the locales of rift nucleation and played a fundamental role in the mechanism of rift propagation along reactivated ancient shear zones [15-18]. These intra-cratonic rifts are referred to as Gondwana basins.

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The Gondwana basins are linearly arranged along the present day river valleys viz. Koel-Damodar, Son-Mahanadi and Pranhita-Godavari (**Figure 1(b)**). The sediments are mostly made up of clastics of glacial and glacigene rocks at the base followed by coal measures and red beds at the top [19]. The Talchir Formation, the lowermost member of Gondwana sequence of India, is suggested to be of glacial, glacio-fluvial, glacio-lacustrine and/or glacio-marine depositional environment [20-32]. The Talchir Formation is marked by uniformly deposited olive green sandstone, conglomerate, thinly laminated shales, siltstone, and varves with typical glacigene facies tillite mostly at the base.

The present study is based on modal analysis of

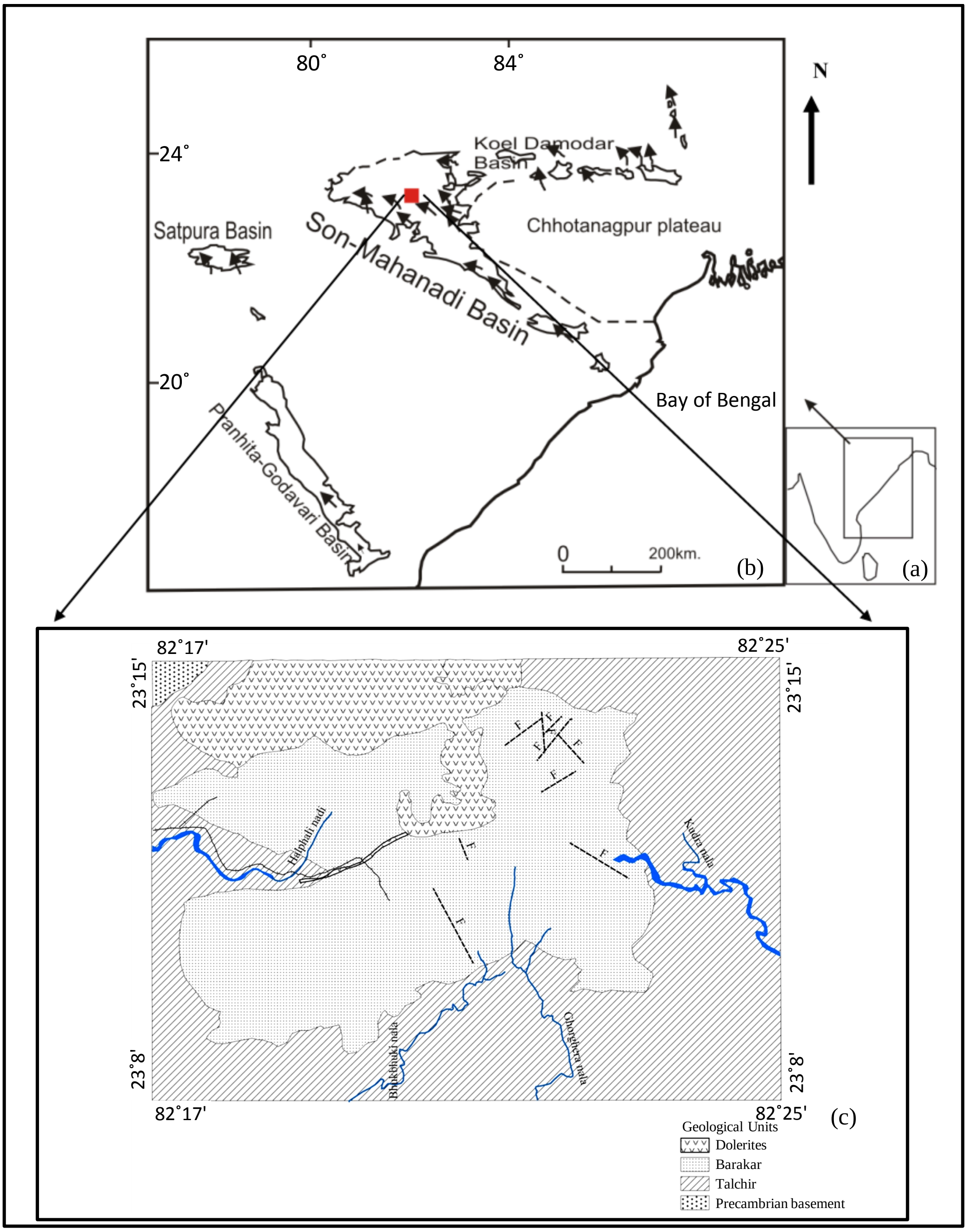

Figure 1. (a) Map of India shown inset; (b) The outline map of Peninsular India showing Gondwana basins and paleohighlands. Arrows indicate direction of Permian-Triassic paleoslope modified by Tewari and Veevers, 1993; (c) Map showing study area modified after Raja Rao 1983.

sandstones of Talchir Formation of Chirimiri, Koriya district, Chhattisgarh state, located in Son-Mahanadi basin (**Figure 1(c)**). The aim of the study is to interpret the possible provenance, tectonic setting and paleoclimate variability that led to the deposition of these sandstones during Permo-Carboniferous period.

2. Geological Setting

The Chirimiri coalfield, the study area, is a part of Son-Mahanadi basin falls between latitudes 23˚8'N to 23˚15'N and longitudes 82˚17'E to 82˚25'E. Talchir Formation is exposed along streams flowing in the vicinity of Chirimiri town. Olive green, thinly laminated shales and medium grained sandstone succeeded by lemon yellow alternate beds of shale and sandstones are found exposed in this area. The Chirimiri area was surveyed by C.S Raja Rao and stratigraphic succession was proposed (**Table 1**) [33].

The Son-Mahanadi graben is one of the largest intracratonic rift basins of peninsular India. The Mahakoshal supracrustal lie in the north of Son-Mahanadi Gondwana basin. The rocks of Sausar mobile belt and Betul supracrustals are exposed in the south, whereas the eastern and south eastern fringes of the Son-Mahanadi basin are constituted by granite-gneissic complex of Chotanagpur terrain and Precambrian rocks of Singhbhum and Bastar craton respectively [34]. To the west of the basin unclassified Precambrian migmatites and geneisses are exposed. Tectonically, the basin has been divided into three blocks *i.e.*, Son, Hasdo-Arand and Mahanadi separated from each other by ENE-WSW trending prominent basement ridge [35]. Spatial distribution of rock units, variation in the thickness of sediments, different disposition of structural elements and contrasting lineament-trends of these three blocks suggest that each underwent a different sedimentation and tectonic history [35].

3. Material and Methods

The current study deals with petrographic interpretations of Talchir sandstones in Chirimiri area. 50 Talchir sandstone samples have been collected along the stream cuttings in and around Chirimiri, where they are found exposed. The streams from where these samples have been collected are Halphali, Kudra, Bhukbhuki, and Ghorghera (**Figure 1(c)**). Out of these 50, only 29 representative samples of sandstone were selected for petrographic studies. Thin sections of the selected samples were prepared by standard technique. Modal analysis of samples was carried out using point counting method to determine the quantitative mineralogical aspects of these sandstones. About 350 points per thin section were counted (**Table 2**) using Gazzi-Dickenson's method [36]. The counted grains were recalculated into percentage as summarised in (**Table 3**).

Table 1. Stratigraphic succession of Chirimiri, coalfield Koriya district, Chhattisgarh (Raja Rao, 1983).

Age	Formation	Lithology
Upper Cretaceous to lower Eocene (?)	Deccan Traps	Basic flows, dykes and sills.
Lower Permian	Barakar	Essentially sandstone with subordinate Shales and coal seams (230 m to 435 m).
Upper Carboniferous to Early Permian	Talchir	Predominantly olive green shales and Medium to fine grained sandstone.
	UNCONFORMITY	
Precambrian basement		Granite, Gniesses and Quartzite

Table 2. Key for petrographic and other parameters used in this study (modified after Dickinson 1985).

QFR	
Q	Total Quartz grains (Qm + Qp)
Qm	monocrystalline quartz
Qp	polycrystalline quartz
F	Total Feldspar (P + K)
P	Plagioclase
K	alkali feldspar
R	Total rock fragments including chert
QtFL	
Qt	Total quartz grains (Qm + Qp)
Qm	monocrystalline quartz
Qp	polycrystalline quartz
F	Total Feldspar (P + K)
P	Plagioclase
K	alkali feldspar
L	Total lithic fragments
QmFLt	
Qm	monocrystalline quartz
F	Total Feldspar (P + K)
P	Plagioclase
K	alkali feldspar
Lt	Total rock fragments including polycrystalline quartz
QpLvLs	
Qp	polycrystalline quartz
Lv	Total volcanic and Meta-volcanic rock fragments
Ls	Total sedimentary rock fragments
LmLvLs	
Lm	Total metamorphic rock fragments
Lv	Total volcanic rock fragments
Ls	Total sedimentary rock fragments
Qp/F + RF vs. Qt/F + RF	
Qt	Total quartz grains (Qm + Qp)
Qm	monocrystalline quartz
Qp	polycrystalline quartz
F	Total Feldspar (P + K)
RF	Total rock fragments

Table 3. Recalculated detrital composition of Talchir sandstones of Chirimiri area, Koriya district.

S.No	QFR			QtFL			QmFLt			QpLvLs			Qp/(F + R)	Qt/(F + R)	QmPK		
	Q	F	R	Qt	F	L	Qm	F	Lt	Qp	Lv	Ls			Qm	P	K
NT1	71.23	16.44	12.33	60.46	38.37	1.17	71.23	16.44	12.33	0	0	100	0.11	1.52	60.47	0	39.55
NT2	70.42	15.49	14.08	57.89	40.35	1.76	70.42	15.49	14.08	0	0	100	0.21	1.37	56.90	0	43.1
NT3	69.62	18.99	11.39	52.40	43.26	4.34	69.62	18.99	11.39	0	0	100	0.25	1.1	55	15	30
NT5	61.54	19.23	19.23	55.26	39.48	5.26	61.54	19.23	19.23	0	0	100	0.21	1.23	58.33	5.55	36.12
NT7	67.57	18.92	13.51	54.17	29.17	16.7	67.57	18.92	13.51	0	0	100	0.13	1.18	65	0	35
NT8	91.67	4.86	3.47	68.94	28.43	2.63	91.67	4.86	3.47	66.66	0	33.34	0.03	1.38	70.49	4.26	25.25
NT9	80.13	16.03	3.85	68.57	24.58	6.85	80.13	16.03	3.85	0	0	100	0.17	1.55	73.61	2.47	23.92
NT10	73.53	13.24	13.24	76.36	23.64	0	73.53	13.24	13.24	0	0	0	0.12	1.55	76.36	1.81	21.83
NT12	71.11	22.22	6.67	58.1	37.4	4.5	71.11	22.22	6.67	0	0	0	0.06	1.56	60	7.5	32.5
NT13	70.71	20.20	9.09	83.54	16.46	0	70.71	20.20	9.09	0	0	0	0.11	1.56	85.71	1.3	12.99
NT14	71.43	23.81	4.76	62.92	35.96	1.12	71.43	23.81	4.76	33.33	0	66.67	0.26	1.64	63.64	0	36.36
GN1	73.36	18.22	8.41	77.38	17.86	4.76	54.55	27.27	18.18	70	0	30	0.28	2.05	66.66	4.44	28.9
GN2	64.10	25.00	10.90	72.12	21.15	6.73	67.31	21.15	11.54	45.5	0	54.5	0.16	1.54	76	3	21
GN3	67.57	21.62	10.81	69.70	24.24	6.06	69.70	24.24	6.06	0	0	100	0.23	1.68	74.2	3.22	22.58
GN4	61.74	26.85	11.41	61.90	29.25	8.84	60.54	29.25	10.20	13.33	0	86.67	0.03	1.62	67.42	3.02	29.56
GN5	84.52	11.90	3.57	77.65	20.00	2.35	77.65	20.00	2.35	0	0	100	0.2	0.91	79.53	8.43	12.04
GN6	74.65	14.08	11.27	74.20	17.35	8.45	67.74	17.74	14.52	33.33	0	66.67	0.17	2	79.24	0	20.76
GN7	76.11	19.44	4.44	68.75	27.60	3.65	62.50	27.60	9.90	66.67	16.7	16.67	0.21	1.05	69.38	9.82	20.8
GN8	79.40	16.08	4.52	78.61	18.41	2.99	64.68	18.41	16.92	80.02	11.4	8.57	0.7	1.95	77.84	1.2	20.96
GN9	79.14	10.07	10.79	63.16	29.47	7.37	56.00	32.00	12.00	44.44	0	55.56	0.16	1.69	65.85	3.04	31.11
GN10	71.64	22.39	5.97	70.78	26.23	2.99	68.81	26.24	4.95	40	10	50	0.06	1..46	72.39	2.6	25.01
GN11	82.05	11.11	6.84	87.27	10.91	1.82	82.50	10.00	7.50	80	0	20	0.15	1.92	87.27	2	10.73
BBK1	71.43	14.29	14.29	49.25	42.25	8.50	45.54	43.56	10.90	0	14.29	85.71	0.11	0.83	51	0	49
BBK3	59.70	22.39	17.91	53.00	44.00	3.00	52.11	45.07	2.82	100	0	0	0.05	1.14	53.62	0	46.38
BBK4	63.37	28.71	7.92	70.00	24.00	6.00	53.33	26.67	20.00	100	0	0	0.05	1.43	42.3	3.84	53.86
BBK5	51.28	25.64	23.08	41.00	53.00	6.00	39.64	54.05	6.31	0	33.33	66.67	0.17	1.17	45.5	0	54.5
BBK6	73.96	20.71	5.33	38.89	55.56	5.56	38.89	55.56	5.55	100	0	0	0.35	0.63	63.69	10.71	25.6
BBK7	77.92	10.39	11.69	63.32	33.67	3.02	60.80	38.07	1.13	90	0	10	0.26	1.72	66.66	16.66	16.68
KN3	74.11	14.29	11.61	56.62	40.44	2.94	56.92	42.31	0.77	75	0	25	0.03	1.3	57.37	0	42.63

4. Petrography

These sandstones are predominantly coarse to medium grained. Quartz is the chief component of these thin sections. It occurs in three varieties, monocrystalline, polycrystalline, and stretched (Plates 1(a) and (b)), the percentage of quartz ranges from 38.89 to 83.54 percent. The mono-crystalline quartz has both straight to slightly undulatory extinction with angular to subrounded grains. Detrital feldspar comes next to quartz, followed by rock fragments. Feldspar form 10.9 to 55.56 percent in these sandstones followed by rock fragments which range from 3.47 to 23.08 percent. Three varieties of feldspar, that is, orthoclase, plagioclase and microcline have been recorded in these sandstones (Plates 1(c)-(e)). Feldspar grains are fresh, coarse to medium in size and sub rounded in shape. Some feldspar grains also exhibits slight alteration (Plate 1(d)). Orthoclase is more abundant than rest of the feldspar varieties. Heavy minerals observed in these thin sections include zircon, rutile, garnet and epidote, along with rock fragments of granite/gneiss, schist (Plate 1(g)), chert, shale and siltstone. Clay matrix is the common binding material present, along

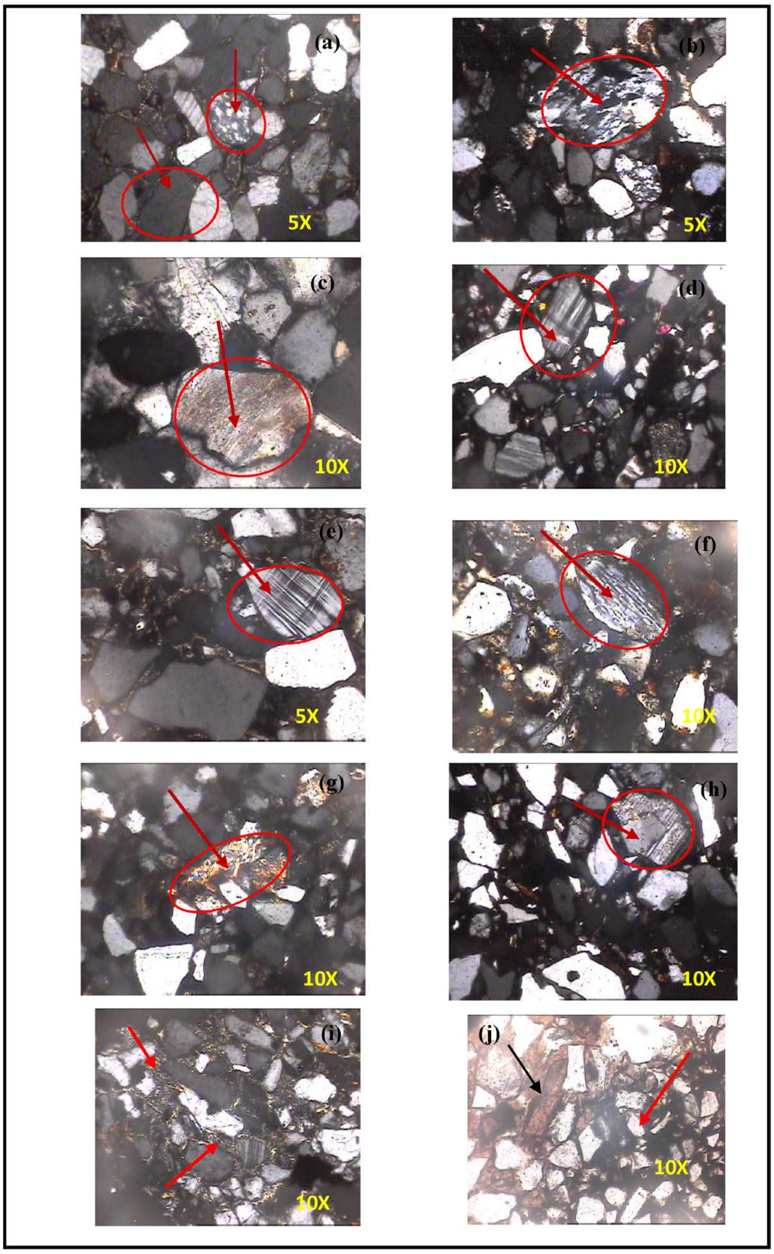

Plate 1. **(a) Photomicrographs of Talchir Formation of Chirimiri area, Koriya district, Chhattisgarh, arrows showing monocrystalline quartz grains and polycrystalline quartz; (b) Stretched quartz; (c) Orthoclase grain showing iron staining; (d) Plagioclase grain slightly altered; (e) Microcline grain; (f) Perthite grain; (g) Schist fragment; (h) Plagioclase grain with inclusion of quartz; (i) Pore filling clay matrix; (j) Undifferentiated matrix (black in colour) and Iron cement (black arrow).**

with ferruginous cement occurring at the edges of the grain or in small patches. Pore filling matrix is also common in these sandstones of Talchir Formation (**Plate 1(i)**) Undifferentiated matrix (**Plate 1(j)**) and few patches of calcite cement have also been encountered in framework of some of these studied samples.

The studied Talchir sandstone specimens of Chirimiri area have been classified according to Folk's classification [37] into three categories viz arkose, subarkose, and lithic arkose (**Figure 2**).

5. Provenance, Tectonic Setting and Paleoclimate

The studied sandstones of Talchir Formation, Chirimiri area have been plotted in QtFL diagram (**Figure 3(a)**), where most of the samples concentrate on continental block provenance and recycled orogen. QmFLt ternary plot also shows the same result (**Figure 3(b)**). The QmPK plot (**Figure 4(a)**) of the studied samples shows that these Talchir sandstones have been derived from continental block provenance. The QpLvLs (**Figure 4(b)**)

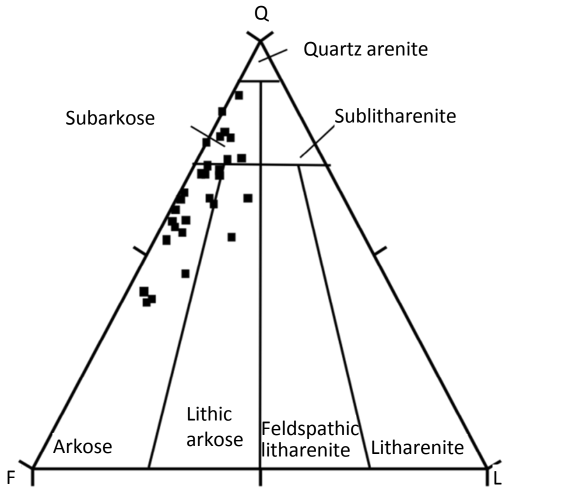

Figure 2. **Classification of Talchir sandstone, Chirimiri area, Koriya district, Chhattisgarh (after Folk, 1980).**

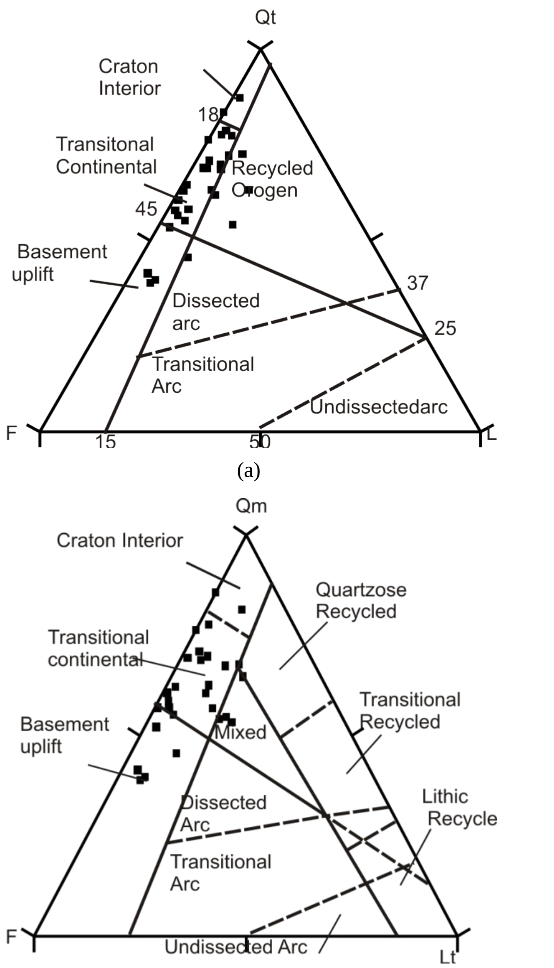

Figure 3. **(a) Triangular diagram QtFL of Talchir sandstones, Chirimiri, Koriya for Provenance (after Dickinson *et al.*, 1985). (b) Triangular diagram QmFLt of Talchir sandstones, Chirimiri. Koriya for Provenance (after Dickinson *et al.*, 1985).**

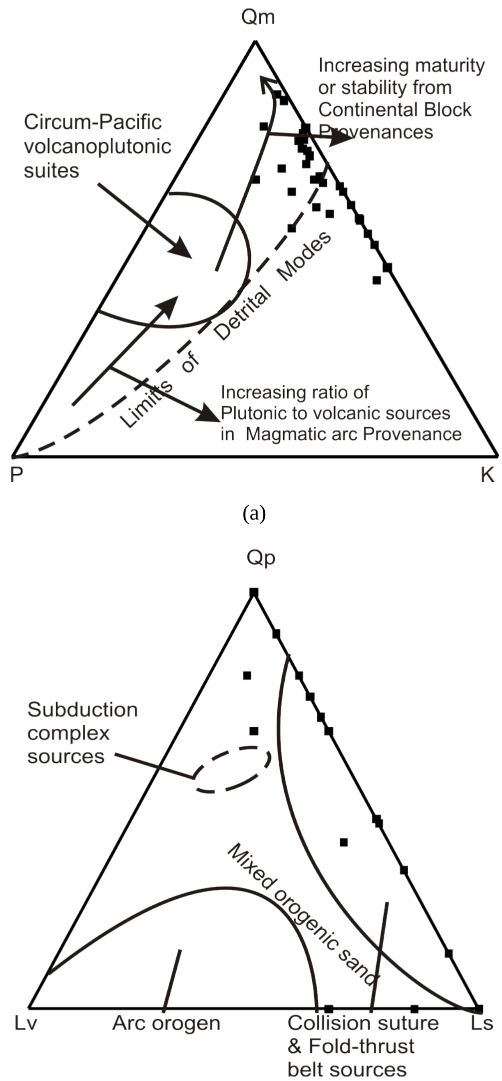

Figure 4. **(a) Triangular diagram QmPK of Talchir sandstones, Chirimiri, Koriya district, for Provenance (after Dickinson *et al.*, 1985). (b) Triangular diagram QpLvLs of Talchir sandstones, Chirimiri, Koriya district for Provenance (after Dickinson *et al.*, 1985).**

diagram based on lithic fragments population, suggests collision suture and fold thrust belt as source of these sandstones. The study of past climate of Permo-Carboniferous period is based on mineral composition of sandstone using bivariate plot between Qt/(F + R) vs. Qp/(F + R) as shown in (**Figure 5**). The samples show variation in climate, changing gradually from semi-arid to semi-humid.

6. Results and Discussion

The modal analysis of studied Talchir sandstones (**Table 3**), plotted on ternary diagram indicates that the sediments of Talchir Formation of Chirimiri, Koriya district,

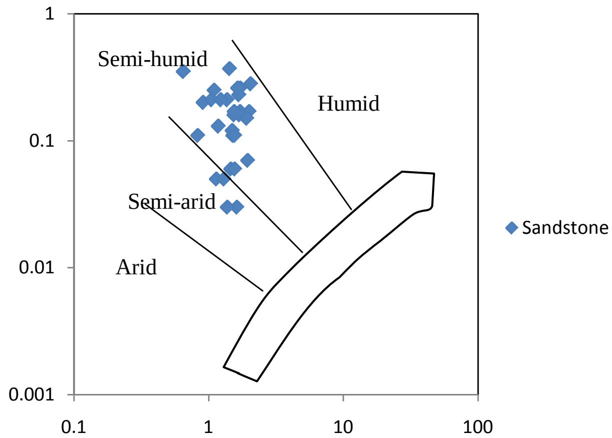

Figure 5. Bivariate log-log plot of Qt/(F + R) and Qp/(F + R) ratios of Talchir sandstones, Chirimiri, Koriya district, in climate discrimination diagram (after Suttner and Dutta, 1986).

Chhattisgarh were derived from continental block provenances and recycled orogen (**Figure 3(a)**). Within these major provenances sediments were derived from transitional continental block, basement uplift and small inputs also came from mixed field as shown in (**Figure 3(b)**). Continental block comprises variety of rocks, ranging from felsic-intermediate-mafic igneous, metamorphic and sedimentary to volcano-sedimentary assemblages. Recycled orogen sediments are sedimentary and subordinate volcanic rocks, which are metamorphosed and exposed to the surface by erosion and uplift of fold belts and thrusts. Some of these sediments were derived from recycled orogeny as shown in (**Figure 4(b)**). It can be interpreted from the present study that these sediments were derived from transitional continental region of continental block, which are generally of intermediate composition and provided compositionally immature to sub-mature sediments to the basin as shown in (**Figure 4(a)**). The palaeoflow data indicates that, in this part of peninsular India depositing streams were flowing from East-South- East to West-North-West during late Paleozoic [22]. On the basis of type of detrital framework components and available paleocurrent data it may be suggested that the provenance of the studied sandstone samples was probably Chotanagpur/Singhbhum craton and some other metasediments exposed in the vicinity of the basin. The studied samples show (**Figure 5**) that during late Palaeozoic era the climate changed gradually due to drifting of Indian sub continent towards the equator [8].

The quartz grains in shape ranges from angular to subrounded with strain lamellae in some of these grains. Angularity of some quartz grains indicate that these are first cycle of erosion sediments or have suffered some short distance of transportation whereas subrounded to rounded grains are either of second cycle or have been transported for longer distance. The preponderance of non-undulatory monocrystalline quartz over undulatory quartz suggests plutonic source. Automorphic inclusion of heavy mineral like zircon and tourmaline in monocrystalline quartz and grains of perthite (**Plate 1(f)**) are direct evidences of granitic source. Some mono crystalline quartz, are free from inclusions of heavy mineral and shows slight undulose extinction signifying that older gneiss or schist rocks might be the source [38]. The presence of iron oxide cement on feldspar grains also depict humid climate [10,39,40].

7. Conclusions

On the basis of the petrological data of the sandstone specimens of Talchir Formation (Permo-Carboniferous) collected from Chirimiri, Koriya district, Chhattisgarh, the following conclusions can be drawn:

1) These sandstones samples are compositionally immature to submature and have been classified as arkosic, subarkosic and lithic arkosic type.

2) Constituent grains of these sediments suggest their derivation continental block provenance.

3) Paleocurrent data indicate that the source area of these sandstones was somewhere in the East-South-East of the basin, which may be Chhotanagpur/Singhbhum complex with some contribution from Bastar craton also.

4) During the deposition of these Talchir sandstones, climate changed from semiarid to semi humid.

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