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Palynomorphs of Gondwanic affinities in the Oligo-Miocene sediments of Kargil Molasse Group, Ladakh, India

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ABSTRACT

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The Kargil Molasse Group of northwest Ladakh Himalaya is divided into Kargil, Tharumsa and Pashkyum formations, composed mainly of sandstone, mudstone, siliceous clay and grey to dark brown carbonaceous shale. Plant fossils recorded in these sequences are represented by angiosperm leaf impressions, pteridophytic spores, gymnosperm and angiosperm pollen grains, algal and fungal remains and gyrogonites of charophytes. The present study deals with reworked palynoflora of Gondwanic affinity of late Permian (Tatarian) and early Triassic (Scythian) age embodied in the late Cenozoic sediments of Tharumsa Formation of northwest Himalaya. The occurrence of reworked palynomorphs in the younger sediments is very significant. It can be interpreted that Palaeozoic and Mesozoic Tethyan sediments, deposited along the northern margin of Indian Plate, were transported and eroded and eventually got accumulated in the Tharumsa Formation during the process of orogenesis in this region.

Key-words—Reworked palynomorphs, Kargil Molasse, Tharumsa Formation, Miocene, Ladakh.

कारगिल मोलास समूह, लद्दाख, भारत के अल्प-मध्यनूतन अवसादों में गोंडवानी बंधुताओं के परागाणुसंरुप

माधव कुमार, अमित के. घोष, राम अवतार एवं आर.सी. मेहरोत्रा

सारांश

उत्तर पश्चिम लद्दाख हिमालय का कारगिल मोलास समूह के घटक कारगिल, तरुम्सा एवं पश्क्यूम शैल मुख्यतः बालुकाश्म, पंकाश्म, सिलिकामय मृत्तिका एवं धूसर से गहरे भूरे कार्बनिक शैल संलक्षणों से युक्त है। इन संलक्षणित अनुक्रम में आवृतबीजी पत्ती छापें, टैरिडोफाइट बीजाणु, अनावृत एवं आवृतबीज परागकण, शैवाल, कवक तथा कैरोफाइट गाइरोगोनाईट समाहित हैं। प्रस्तुत अध्ययन इन तरुम्सा शैलसमूह के समयोत्तर नूतनजीवी अवसादों में समाहित अंतिम पर्मियन (ततारियन) एवं प्रारंभिक ट्राइऐसिक (सायथियन) परागकणों व बीजाणु तथा उनकी गोंडवानिक समानता तथा उनकी पुनः चक्रण प्रक्रिया को प्रदर्शित करता है। इन तरुण अवसादों में पुनः चक्रत परागाणु आकृतियों की उपलब्धता अतिमहत्वपूर्ण है, जो तरुमसा शैलसमूह में पुराजीवी तथा मध्य जीवी तैथियन अवसादों की पुनः चक्रण की प्रक्रिया को प्रदर्शित करता है तथा इनका भारतीय आधार पट्टिका के उत्तरी छोर पर संचयन एवं पर्वतन की क्रियाविधि परिलक्षित करता है।

संकेत-शब्द—पुनर्रचित परागाणुसंरुप, कारगिल मोलास, तरुम्सा शैलसमूह, मध्यनूतन, लद्दाख।

Palinomorfos de afinidades Gondvânicas nos sedimentos Oligomiocenos do Grupo Molassa Kargil, Ladakh, Índia

RESUMO

O grupo Molassa Kargil do noroeste do Himalaya Ladakh está dividido nas formações Kargil, Tarumsa and Pashkyum, compostas principalmente de arenitos, argilitos, argila silicosa e folhelho carbonoso cinza a castanho escuro. Fitofósseis registrados nestas sequências são representados por impressões de folhas de angiospermas, esporos pteridofíticos, grãos de

pólen gimnospérmicos e angiospérmicos, restos de algas e fungos e girogonites de carófitas. O presente estudo trata de uma palinoflora retrabalhada, de afinidade gondvânica de idade neopermianoa (Tatariano) e eotriássica (Scytiana = Induana + Olenekiana), envolvidas por sedimentos neocenozóicos da Formação Tharumsa, noroeste do Himalaia. A ocorrência de palinomorfos retrabalhados em sedimentos mais jovens é muito significativa. Pode-se deduzir que os sedimentos mesozóicos tetianos e paleozóicos, depositados ao longo da margem norte da placa indiana, foram transportados, erodidos e, eventualmente, acumulados na Formação Tharumsa, durante o processo de orogênese nesta região.

Palavras-chave—Palinomorfos retrabalhados, Kargil Molassas, Formação Tharumsa, Mioceno, Ladakh.

INTRODUCTION

The collision of India and Asia and its consequences for the upliftment of Himalayan and Tibetan Plateaus caused increased influx of clastic materials to the various depositional sites in the Ladakh region. The Ladakh Molasse Group, by virtue of its close vicinity to the suture zone between the Indian and Asian plates, as well as to the Tibetan Plateau, was undergoing upliftment. In the present study, palynomorphs of Gondwanic affinities have been recorded in the Oligo-Miocene sediments of Kargil Molasse Group, Ladakh, India. This has got strong relationship amongst tectonics, climate and depositional processes in the region. Occurrence of reworked Gondwanic palynomorphs is common in the

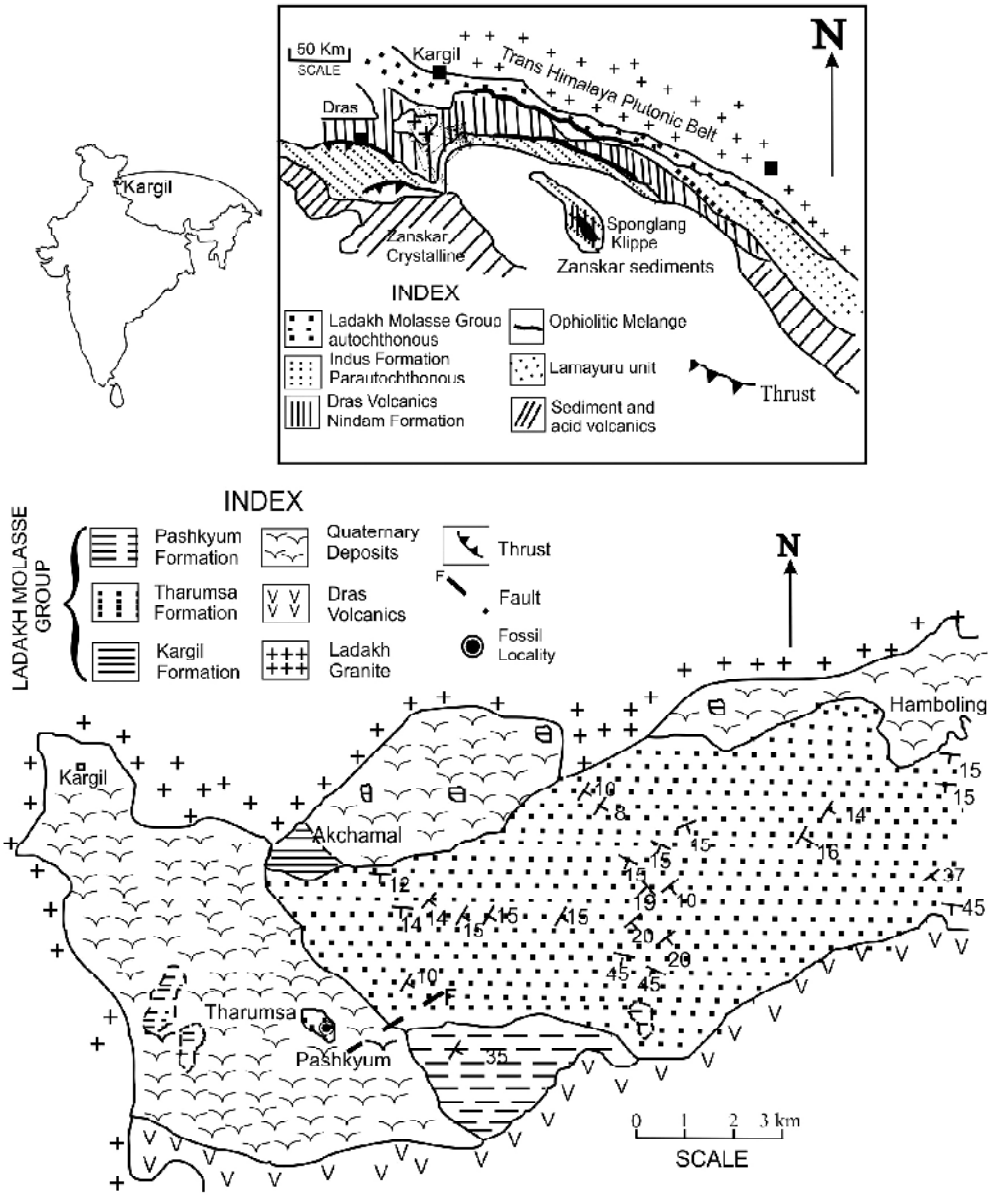

Fig. 1—A map showing the fossiliferous localities in Kargil area, Ladakh (after Nanda & Sahni, 1998).

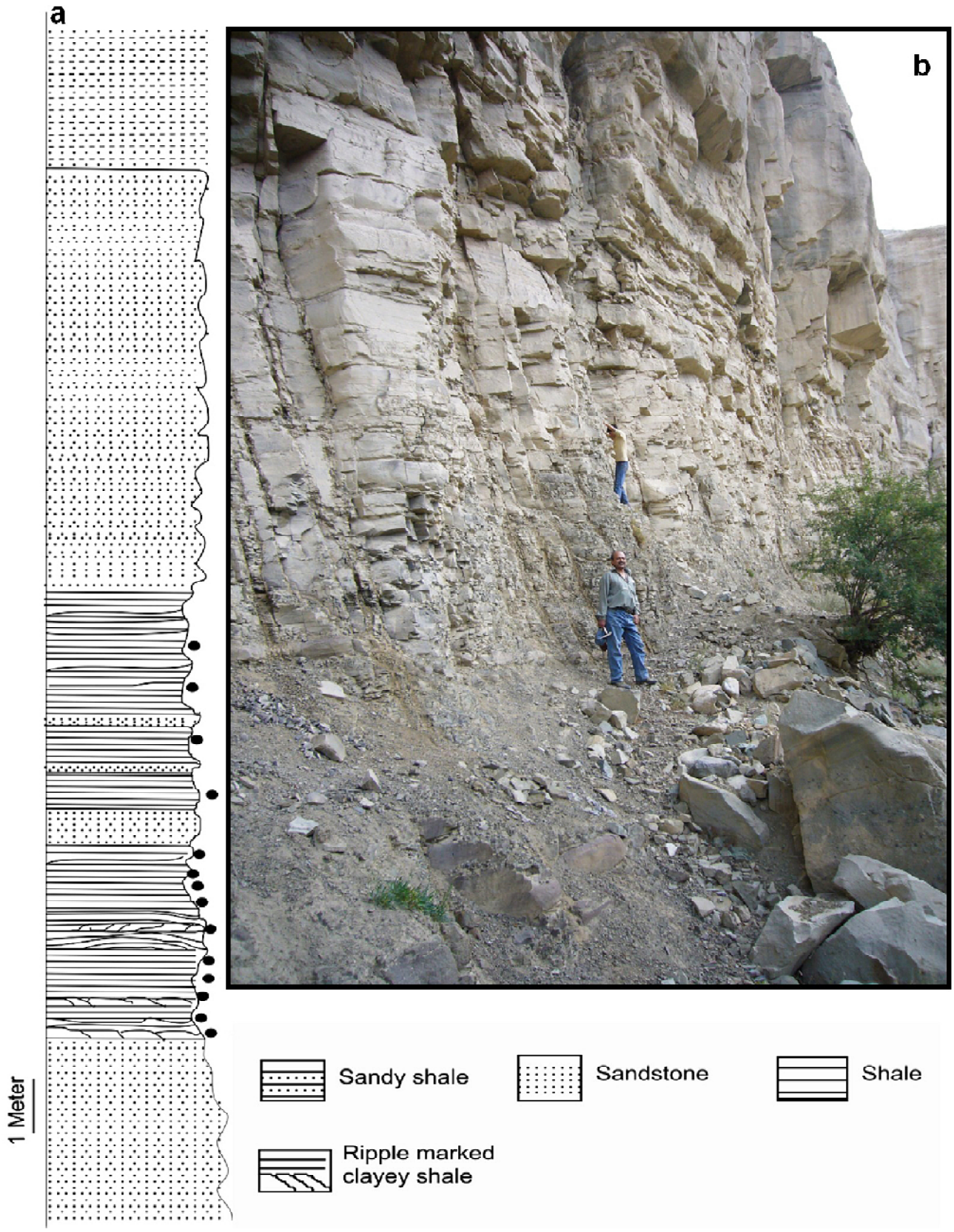

Fig. 2—(a). Litholog of the middle part of Tharumsa Formation showing locations of yielding samples. (b). A photograph of the exposed section of the middle part of Tharumsa Formation.

Spores	**Monosaccate pollen**	**Taeniate Bisaccate pollen**
Anapiculatisporites	*Barakarites*	*Arcuatipollenites*
Apiculatisporis	*Callialasporites*	*Chordasporites*
Baculatisporites	*Densipollenites*	*Corisaccites*
Brevitriletes	*Enzonalasporites*	*Dicappipollenites*
Callumispora	*Goubinispora*	*Guttulapollenites*
Cingulizonates	*Kamthisaccites*	*Infernopollenites*
Conbaculatisporites	*Parasaccites*	*Taeniaesporites*
Convertubisporites	*Playfordiaspora*	
Cyathidites	*Plicatipollenites*	**Striate Bisaccate pollen**
Cyclogranisporites	*Striomonosaccites*	*Circumstriatites*
Densoisporites	*Virkkipollenites*	*Crescentipollenites*
Dictyotriletes		*Distriatites*
Godavarisporites	**Non-Striate Bisaccate pollen**	*Faunipollenites*
Gondisporites	*Alisporites*	*Gondwanipollenites*
Horriditriletes	*Brachysaccus*	*Hamiapollenites*
Indotriradites	*Cuneatisporites*	*Hindipollenites*
Jayantisporites	*Falcisporites*	*Lahirites*
Kraeuselisporites	*Ibisporites*	*Primuspollenites*
Lacinitriletes	*Klausipollenites*	*Protohaploxypinus*
Laevigatosporites	*Krempipollenites*	*Rhizomaspora*
Leiosphaeridia	*Minutosaccus*	*Striatites*
Leiotriletes	*Nidipollenites*	*Striatoabietites*
Limatulasporites	*Pinuspollenites*	*Striatopodocarpites*
Lundbladispora	*Podocarpidites*	*Verticipollenites*
Microbaculispora	*Rimaesporites*	
Microfoveolatispora	*Sahnites*	**Others**
Neoraistrickia	*Samaropollenites*	*Araucariacites*
Osmundacidites	*Satsangisaccites*	*Aratrisporites*
Polycingulatisporites	*Scheuringipollenites*	*Decussatisporites*
Rajmahalispora	*Vestigisporites*	*Ginkgocycadophytus*
Verrucosisporites	*Voltziaceaesporites*	*Weylandites*

Fig. 3—Check list of reworked spore/pollen of Gondwanic affinity.

northwest Ladakh Himalaya symbolizing tectonic upliftment, erosion of pre-existing rocks (possibly from the Zanskar Platform and Lamayuru Complex) and their transportation to various depositional sites. Bhandari *et al.* (1977) recorded recycled Gondwanic palynomorphs of late Jurassic-early Cretaceous affinity without any taxonomic assignment. Upadhyay *et al.* (2004) recorded several late Permian and early Triassic palynomorphs from the Nindam Formation and middle to late Jurassic palynofossils from the NW of Khangral Village of Lamayuru Complex. Ram-Awatar (2008) recorded early to late Permian palynofossils from Shyok Suture Zone of Ladakh Himalaya. The present reworked Gondwanic palynofossils closely resemble the late Permian and early Triassic palynoflora recorded by Upadhyay *et al.* (2004) and Ram-Awatar (2008). The Oligo-Miocene spores and pollen grains recorded in the Tharumsa Formation indicate that the deposition took place under fluvio-lacustrine condition. Thus, record of a rich and diversified assemblage of reworked Gondwanic palynomorphs is significant for deciphering the depositional history of Tharumsa Formation in the Kargil Molasse Group.

GEOLOGICAL SETTING

The late Oligo-Miocene Sequence of Ladakh Molasse Group was deposited over the Ladakh Plutonic Complex (= Ladakh Batholith) in the western part of Ladakh, i.e. in the Kargil area. It comprises three lithounits viz. Kargil, Tharumsa and Pashkyum in ascending order (Bhandari *et al.,* 1977). The total thickness of the Kargil Molasse Group is ~ 1750 m and the rocks are beautifully exposed along the Wakha River Section (Fig. 1). The Kargil Formation comprises purplish brown, bluish shale and purple to greenish grey sandstones. The sediments of Tharumsa Formation are best exposed at the northwest of Akschamal Village, along Wakha River. The formation is about 700 m thick containing alternations of thick, well bedded sandstone and mudstone/carbonaceous clay with intercalation of thin conglomerate beds. The Pashkyum

Sample No. / Palynotaxa	8	7	6	5	4	3	2	1
Alisporites	2	3	10	9.5	8.5	9.5	7	5.5
Anapiculatisporites	-	-	-	-	-	-	1	0.5
Apiculatisporites	-	2	-	-	0.5	1	-	1
Araucariacites	5	1	3	3	-	1.5	-	-
Aratrisporites	-	1.5	-	-	1	-	-	-
Arcuatipollenites	5	6	3.5	4	3	1	3	2.5
Baculatisporites				0.5				
Brachysaccus	-	-	-	-	1	-	1	1.5
Brevitriletes	-	-	2	-	1	-	0.5	1
Callialasporites	-	-	-	1	1	-	-	-
Callumispora	2	-	-	-	-	-	-	-
Chordasporites	-	-	-	-	-	1	-	-
Circumstriatites	-	0.5	-	-	1	1	2	-
Cingulizonates	-	1.5	2.5	-	1.5	1	1	-
Conbaculatisporites	-	-	-	-	-	1	-	0.5
Convertubisporites	-	-	-	-	0.5	1	-	-
Corisaccites	-	0.5	-	-	1	-	-	0.5
Crescentipollenites	2	2.5	1.5	3	1.5	2.5	3	2.5
Cuneatisporites	-	2	1.5	1	3.5	-	-	1
Cyathidites	-	-	-	1	-	-	-	-
Densipollenites	3	0.5	1.5	1.5	3.5	4	3	2
Densoisporites	1	-	4	1	3	2.5	1.5	1.5
Dictyotriletes	-	-	1	1	-	0.5	-	2
Distriatites	2	1	1	-	1	2.5	-	-
Enzonalasporites	-	-	-	-	-	2	3.5	1.5
Falcisporites	3	9	6	6.5	8	9	6.5	6
Faunipollenites	26	11	9	10.5	12	8	6	7.5
Godavarisporites	1	-	-	-	-	0.5	-	1
Gondisporites	2	3.5	0.5	3.5	-	1.5	-	3
Gondwanipollenites	1	-	2	-	1	0.5	0.5	-
Goubinispora	-	1	1	1	1.5	1.5	1	1.5
Hamiapollenites	3	1.5	2.5	1.5	0.5	2	1	1
Hindipollenites	-	1	-	-	-	-	-	-
Horriditriletes	-	-	-	1	1	-	1	3
Ibisporites	1	-	-	2	-	0.5	-	1
Indotriradites	-	-	1	0.5	-	-	0.5	-
Infernopollenites	2	-	-	-	2.5	-	1.5	3.5
Jayantisporites	2	-	-	1	-	0.5	-	-
Kamthisaccites	-	-	-	-	-	-	-	1
Klausipollenites	1	3.5	4	2.5	7.5	7	3	4.5
Kraeuselisporites	-	-	-	-	-	-	-	1
Lacinitriletes	-	-	1	-	-	1	0.5	-
Lahirites	2	-	-	-	2.5	-	1.5	3.5
Laevigatosporites	0.5	-	1	-	1	2	-	0.5
Leiosphaeridia	-	-	-	2	-	-	3	1
Leiotriletes	1	0.5	-	-	-	1.5	-	0.5
Limatulasporites	-	-	-	-	1.5	1.5	1.5	1
Lundbladispora	5	4.5	3	3	6	3	6	5.5
Microbaculispora		-	1	1	0.5	1	1	1
Microfoveolatispora	-	1	0.5	0.5	1	1	1	1
Minutosaccus	-	3	-	-	-	2	1	0.5
Neoraistrickia	-	-	-	-	0.5	-	-	-

Osmundacidites	-	2	-	1	0.5	1.5	2	1
Parasaccites	3	3	3.5	1	1	1	4	2.5
Pinuspollenites	2	3	3	3	2	1.5	1.5	1.5
Playfordiaspora	-	3	1	1.5	3	1.5	1.5	1.5
Podocarpidites	1	-	-	2	-	1	1	0.5
Polycingulatisporites	-	-	0.5	1	-	-	0.5	1
Primuspollenites	-	1.5	-	-	-	-	1.5	-
Protohaploxypinus	-	1	1	1	1	0.5	1	1
Rajmahalispora	-	-	-	0.5	2	0.5	1	-
Rimaesporites	-	1.5	3.5	1.5	1.5	3	2	4
Rhizomaspora	0.5	1	-	1	-	1	1	1
Sahnites	1	-	-	-	-	-	-	-
Samaropollenites	-	3	2	3	1	3	2	1
Satsangisaccites	1	-	-	1	1	1	-	-
Scheuringipollenites	-	0.5	1	1.5	0.5	1	3	1
Striatoabietites	-	-	0.5	-	-	-	1	1
Striomonosaccites	-	-	-	1.5	-	-	1	1.5
Striatopodocarpites	20	14.5	16	16	11	9.5	8	7
Striatites	-	1.5	1	2.5	1	1	2	1
Taeniaesporites	-	3	3.5	3	1	3.5	2	1
Verrucosisporites	2	1	1.5	3	1.5	1	2.5	3.5
Verticipollenites	1	3	3.5	1.5	1.5	1.5	3	3.5
Vestigisporites	-	2.5	-	-	-	-	-	-
Virkkipollenites	-	-	0.5	1.5	-	1	2	-
Voltziaceaesporites	-	-	-	-	-	0.5	-	-

Fig. 4—Frequency of spore/pollen of reworked spore/pollen of Gondwanic affinity.

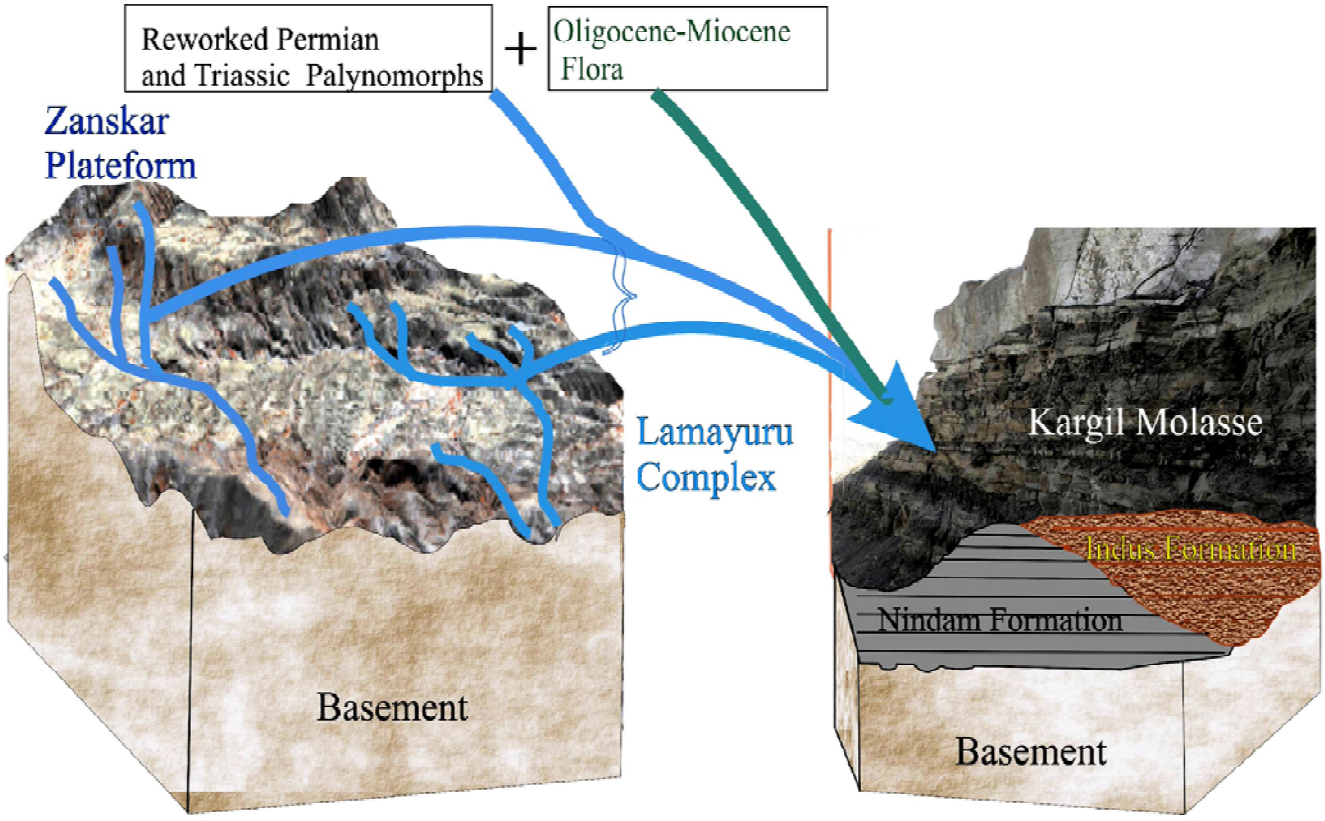

Fig. 5—Conceptual model of the possible erosion, transportation and re-deposition of pre-existing Gondwanic sediments of late Permian and early Triassic age situated away from the accommodation sites.

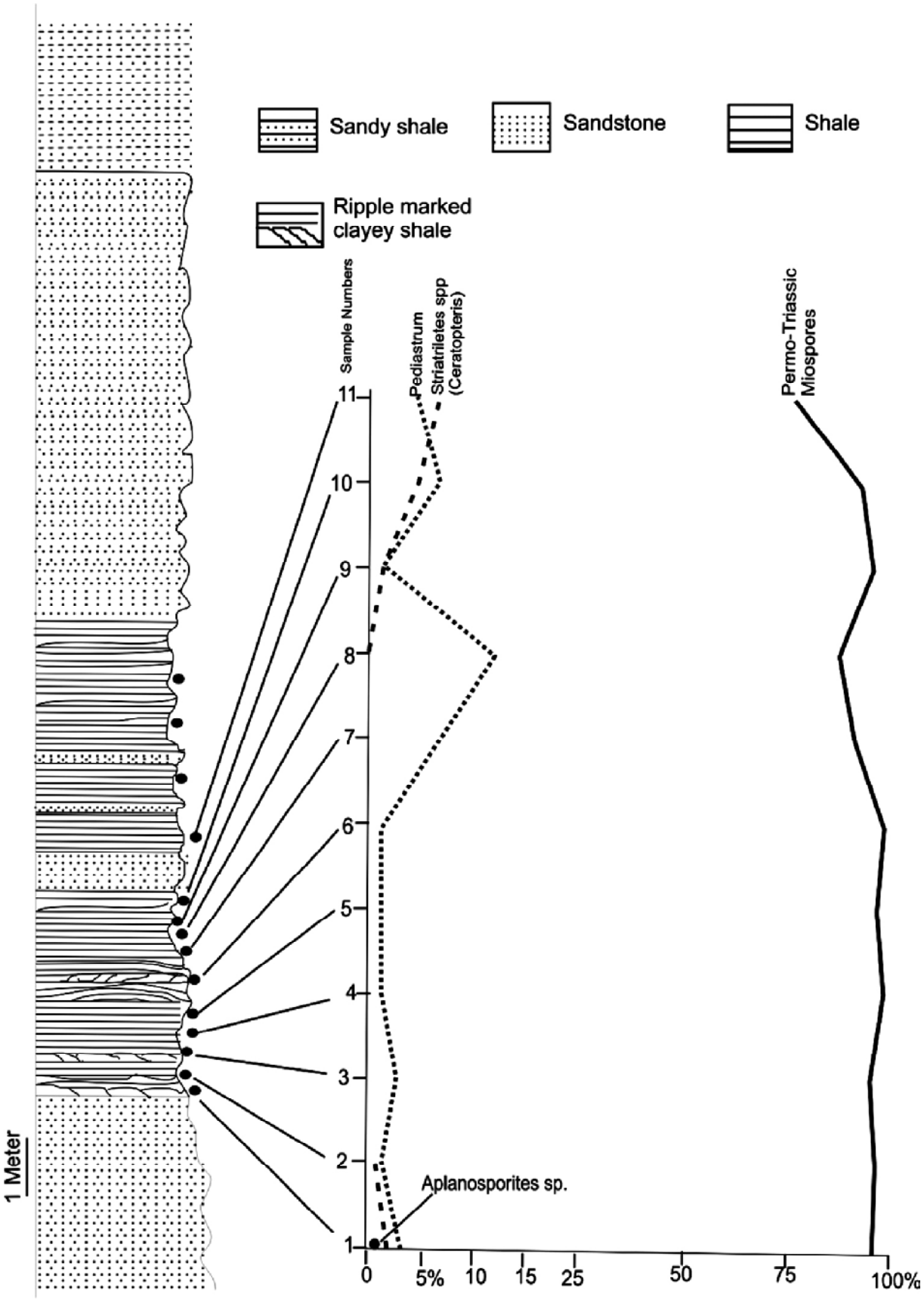

Fig. 6—Showing frequency of various groups of palynomorphs.

Formation is dominated by purple coloured sandstone and mudstone. All three lithounits of Ladakh Molasse Group contain molluscs, vertebrates and plant fossils (Sahni & Bhatnagar, 1962; Tewari & Dixit, 1971; Tewari & Sharma, 1972; Bhandari *et al.,* 1977; Mathur, 1983; Nanda & Sahni, 1990, 1998; Kumar *et al.,* 1996). Based on the presence of *Iberomeryx* (= *Cryptomeryx*) *savagei* and *Lophiomeryx kargilensis* in the lower part of the Kargil Molasse Group an upper Oligocene age was assigned for the Kargil and Tharumsa formations and based on the occurrence of vertebrate fauna *Hyoboops palaeindicus*, a lower Miocene age was assigned for the Pashkyum Formation (Nanda & Sahni, 1990, 1998; Kumar *et al.,* 1996). However, the Tharumsa and Pashkyum formations have so far not yielded any age diagnostic plant fossils, but being stratigraphically younger these units are presumably of Miocene age; though, the Pashkyum Formation may also extend up to the Pliocene (Mathur, 1983).

MATERIAL AND METHODS

Considering the meagre palaeobotanical work in the Kargil area, two field trips were undertaken in July, 2008 and August, 2009 to make a systematic collection of plant remains. Samples for the present study were collected from the middle part of Tharumsa Formation exposed along the Wakha River (34º32'49.17" N; 76º09'45.5" E, Δ 2807 m) near the Tharumsa Village (Fig. 2 a-b). Out of the 14 samples only 11 samples were found to be productive. For the extraction of spores and pollen grains the samples were crushed and processed with dilute Hydrochloric acid followed by 40% Hydrofluoric and concentrated Nitric acids. Samples treated in these acids were rinsed repeatedly by water until neutral pH was achieved. Three to five percent aqueous KOH solution had been applied on the treated material which was then strained through 20 µm pore-sized sieves. The residue was smeared with polyvinyl alcohol on glass cover slips and mounted on glass slides with Canada Balsam following the standard palynological techniques. The figured slides are kept in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

PALYNOLOGICAL ANALYSIS

Qualitatively reworked Gondwanic palynomorphs are preponderant in the analysed samples. Some early Neogene palynomorphs have also been recorded in addition to spores of *Striatiletes* spp. and some algal and fungal remains. A check list of reworked spore/pollen of Gondwanic affinity recorded from Tharumsa Formation is given in Fig. 3.

The quantitative analysis reveals the dominance of Gondwanic palynomorphs (73-95%). The quantitative

PLATE 1

1. *Callumispora fungosa* Bharadwaj & Tiwari; emend. Tiwari *et al.,* 1989; BSIP Sl. No. 14505, $B_{31/1}$.
2. *Verrucosisporites jonkeri* (Jansonius) Shu & Norris, 1999; BSIP Sl. No. 14488, $M_{36/2}$.
3. *Baculatisporites uniformis* Shu & Norris, 1999; BSIP Sl. No. 14488, $M_{36/2}$.
4. cf. *Callialasporites monoalasporus* Dev, 1961 emend. Maheshwari, 1974; BSIP Sl. No. 14492, U_{41}.
5, 7. *Enzonalasporites vigens* Leschik, 1955 ; BSIP Sl. No. 14495, $S_{41/1}$.
6. *Densipollenites magnicorpus* Bharadwaj, 1962; BSIP Sl. No. 14488, T_{36}.
8. *Densipollenites invisus* Bharadwaj & Salujha, 1964; BSIP Sl. No. 14489, $L_{52/2}$.
9. *Scheuringipollenites maximus* (Hart) Tiwari, 1973; BSIP Sl. No. 14491, $X_{23/2}$.
10. *Alisporites asansolenisis* Maheshwari & Banerjee, 1975; BSIP Sl. No. 14494, $W_{38/3}$.
11. *Striomonosaccites circularis* Bharadwaj & Salujha, 1964; BSIP Sl. No. 14495, $N_{22/2}$.
12. *Striatites sidhiensis* Bharadwaj & Salujha, 1964; BSIP Sl. No. 14491, R_{16}.
13. *Apiculatisporites globosus* (Leschik) Playford & Dettmann, 1965; BSIP Sl. No. 14488, P_{27}.
14. *Anapiculatisporites decorus* Shu & Norris, 1999; BSIP Sl. No. 14493, V_{25}.
15. *Falcisporites stabilis* Balme, 1970; BSIP Sl. No. 14490, $P_{29/1}$.
16. *Plicatipollenites gondwanensis* Lele, 1964; BSIP Sl. No. 14494, S_{21}.
17. *Cingulizonates indicus* Kumaran & Maheshwari, 1980; BSIP Sl. No. 14488, $M_{36/2}$.
18. *Alisporites indicus* Bharadwaj & Srivastava, 1969; BSIP Sl. No. 14491, $P_{49/1}$.
19. *Vesicaspora acrifera* Hart, 1965; BSIP Sl. No. 14488, $G_{25/2}$.
20. *Densipollenites magnicorpus* Bhardwaj & Salujha, 1964; BSIP Sl. No. 14489, $L_{52/2}$.
21. *Klausipollenites angustus* Shu & Norris, 1999; BSIP Sl. No. 14493, R_{20}.
22. *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974, BSIP Sl. No. 14496, $Q_{26/1}$.
23. *Faunipollenites singraulienis* Sinha, 1972, emend Tiwari *et al.,* 1989; BSIP Sl. No. 14497, $U_{25/4}$.
24. *Voltziaceaesporites hetromorphus* Kaus, 1964; BSIP Sl. No. 14491, $U_{11/2}$.
25. *Striatites sidhiensis* Bharadwaj & Srivastava, Shyam.C, 1969; BSIP Sl. No. 14498, L_{20}.
26. *Satsangisaccites nidpurensis* Bharadwaj & Srivastava, 1969; BSIP Sl. No. 14494, $S_{22/1}$.
27. *Rimaesporites potoniei* Leschik, 1955; BSIP Sl. No. 14488, $G_{24/2}$.
28. *Faunipollenites varius* Bharadwaj, 1962, emend Tiwari *et al.,* 1989; BSIP Sl. No. 14493, R_{20}.
29. *Kamthisaccites kamthiensis* Srivastava & Jha, 1986; BSIP Sl. No. 14496, $Q_{26/1}$.
30. *Goubinispora morondavensis* (Goubin) Tiwari & Rana,1980; BSIP Sl. No. 14495, T_{21}.
31. *Arcuatipollenites damudicus* (Tiwari & Rana) Tiwari & Singh, 1995; BSIP Sl. No. 14492, $U_{23/1}$.
32. *Striatopodocarpites decorus* Bharadwaj & Salujha, 1964; BSIP Sl. No. 14492, $P_{33/3}$.
33. *Verticipollenites gibbosus* Bharadwaj, 1962; BSIP Sl. No. 14491 Sl. No. BSIP, Tharumsa II/1/5, Coordinates.
34. *Faunipollenites varius* Bharadwaj, 1962, emend Tiwari *et al.,* 1989; BSIP Sl. No. 14490, $O_{31/2}$.

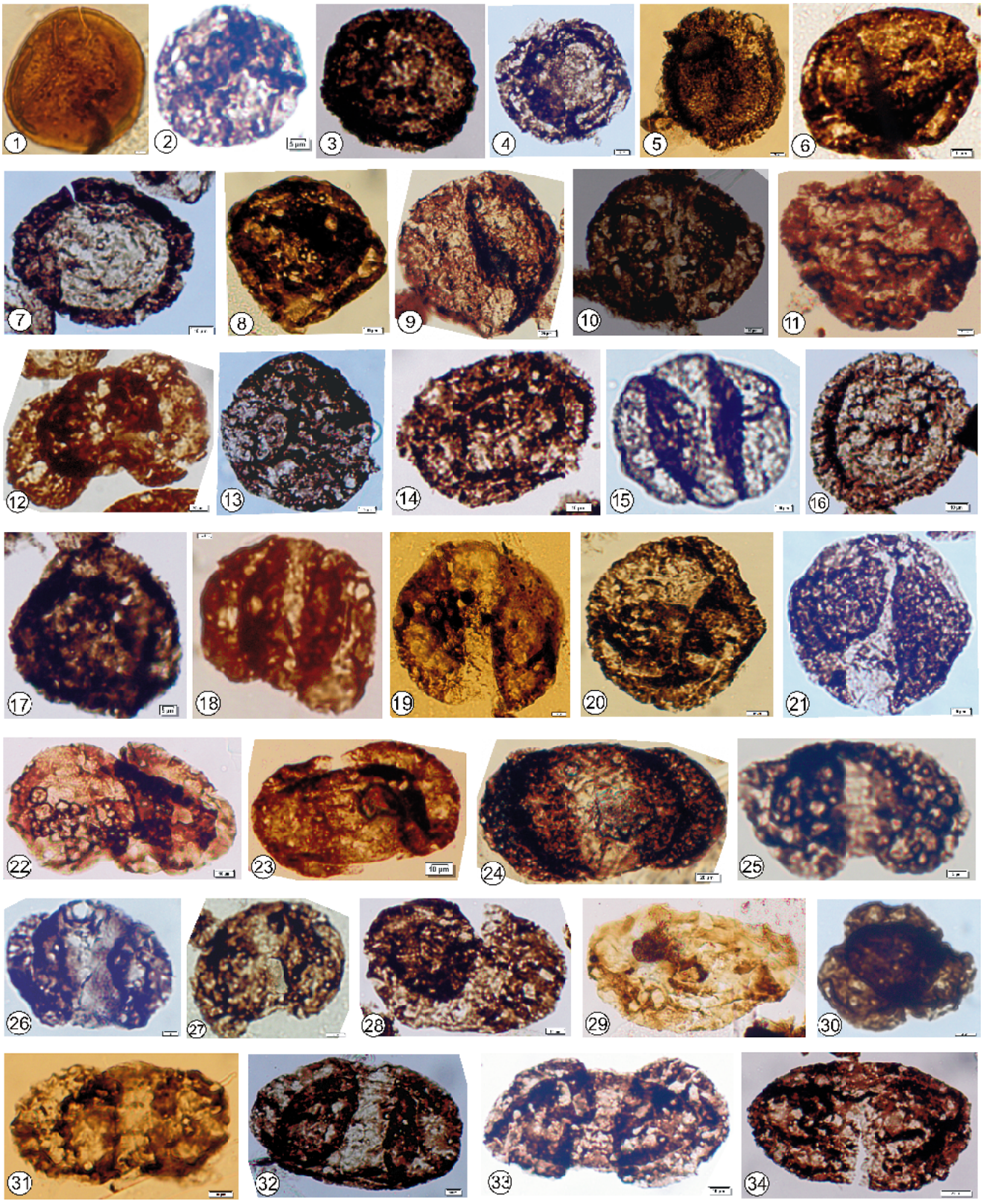
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PLATE 1

distribution of Gondwanic palynomorphs of each sample in alphabetical order is given in Fig. 4.

DISCUSSION

The recovery of late Permian and early to late Triassic palynofossils of Gondwanic affinity from the middle part of the Tharumsa Formation is of great significance. Preservation of the palynomorphs is fair however, most of the forms are distorted and show effect of abrasion with striation marks. In all probabilities, it indicates transportation from a distal source because of tectonic activity in the region. The morphological features of the spore and pollen grains (Pls 1 & 2) exhibit possibility of chemothermal effect on sporopollenin as envisaged by Tiwari *et al*. (1994).

The late Permian palynofossils identified in the middle part of the Tharumsa show the presence of *Faunipollenites varius, Striatopodocarpites decorus, Densipollenites magnicorpus, Gondisporites raniganjensis, Alisporites landianus, Distriatites*, *Hamiapollenites, Arcuatipollenites, Verticipollenites*, *Rhizomaspora, Lahirites, Cuneatisporites* and *Verrucosisporites.* This assemblage is closely comparable with late Permian palynoflora described by Tiwari *et al*. (1980) from Tethyan Kuling Shale exposed in the Malla Johar, Kumaun region and Gungari and Gechang flora in Spiti Valley, Himachal Pradesh (Singh *et al*., 1995). In the Tharumsa Formation occurrence of *Aratrisporites, Densoisporites, Falcisporites, Klausipollenites, Playfordiaspora, Infernopollenites, Lundbladispora, Taeniaesporites, Cingulizonates, Araucariacites, Rimaesporites, Satsangisaccites, Samaropollenites, Kamthisaccites, Limatulasporites, Enzonalasporites, Araucariacites* exhibit early to late Triassic age affiliation. The assemblage shows a close similarity with early to late Triassic palynoflora described from the Noric (Passage Formation) of Malla Johar (Tiwari *et al*., 1980), Lilang Group of Spiti Valley (Singh *et al*., 1995) and Sal Sal Formation (Rimkhim Member), Niti area, Central Himalaya (Tiwari *et al*., 1996).

Occurrence of reworked Gondwanic palynomorphs is very common in Himalaya owing to enormous tectonic activity. The first record of recycled Gondwana palynomorphs (late Jurassic-early Cretaceous) was reported by Bhandari *et al*. (1977) without any justified reasons. Later, Upadhyay *et al*. (2004) recorded late Permian/early Triassic palynofossils from Nindam Formation and middle to late Jurassic palynomorphs from the Lamayuru Complex (~300-400 m NW of Khangral Village). Recently, Ram-Awatar (2008) also recorded early to late Permian palynofossils from Shyok Suture Zone, Ladakh Himalaya.

The sediments of the Lamayuru complex was deposited in a forearc setting and the basin was accretionary (Sinha & Upadhyay, 1997; Clift *et al*., 2000). Based on previous observations it has been suggested that the provenance for deposition of the Lamayuru complex was around the Dras Island Arc (Robertson & Degnan, 1994; Clift *et al*., 2000). However, Upadhyay and Sinha (1998) opined that Lamayuru complex received sediments from the Dras Island Arc, situated north of this formation, as well as from the leading passive edge of the Indian Plate which was situated towards the south

PLATE 2 →

1. *Limatulasporites fossulatus* (Playford) Helby & Foster, 1979; BSIP Sl. No. 14499, $B_{13/1}$.
2. *Polycingulatisporites* sp. cf. *P. circulus* Simoncsics & Kedves emend. Playford & Dettmann, 1965; BSIP Sl. No. 14506, L_{21}.
3. *Osmundacidites baculatus* Tiwari & Rana, 1980; BSIP Sl. No. 14500, T_{13}.
4. *Verrucosisporites verrucosus* Ibrahim, 1932; BSIP Sl. No. 14494, G_{29}.
5. *Densoisporites contactus* Bharadwaj & Tiwari, 1977; BSIP Sl. No. 14487, $K_{22/2}$.
6. *Rajmahalispora* (Leschik) Kumaran & Maheshwari, 1980; BSIP Sl. No. 14498, E_{17}.
7. *Densisporites convensis* Potonie & Kremp, 1954; BSIP Sl. No. 14492, $N_{27/1}$.
8. *Kraeuselisporites septatus* Balme, 1957; BSIP Sl. No. 14497, $L_{46/2}$.
9. *Araucariacites australis* (Cookson) Couper, 1958; BSIP Sl. No. 14493, K_{38}.
10. *Playfordiaspora cancellosa* Maheshwari & Banerjee, 1975; emend. Vijaya, 1999; BSIP Sl. No. 14502, $T_{39/2}$.
11. *Densipollenites magnicorpus* Bharadwaj & Salujha, 1964; BSIP Sl. No. 14489, $L_{52/2}$.
12. *Anapiculatisporites decorus* Shu & Norris, 1999; BSIP Sl. No. 14493, V_{25}.
13. *Conbaculatispora mesozoicus* Klaus, 1960; BSIP Sl. No. 14494, $R_{14/4}$.
14. *Convolutispora perfecta* Kumaran & Maheshwari, 1980; BSIP Sl. No. 14495, $P_{39/4}$.
15. *Goubinispora indica* (Goubin) Tiwari & Rana, 1980; BSIP Sl. No. 14494, $T_{9/1}$.
16. *Samaropollenites specious* Goubin, 1965; BSIP Sl. No. 14489, $K_{26/3}$.
17. *Rimaesporites potoniei* Leschik, 1955; BSIP Sl. No. 14492, $K_{35/2}$.
18. *Pinuspollenites* sp; Raatz, 1937; BSIP Sl. No. 14494, $Q_{16/4}$.
19. *Lundbladispora foveolata* Shu & Norris, 1999; BSIP Sl. No. 14492, $M_{28/4}$.
20. *Satsangisaccites nidpurensis* Bharadwaj & Srivastava, 1969; BSIP Sl. No. 14494, $Q_{8/4}$.
21. *Falcisporites nuthallensis* Balme, 1970; BSIP Sl. No. 14494, $T_{6/1}$.
22. *Brachysaccus triassicus* Tripathi *et al*., 1990; BSIP Sl. No. 14494, $P_{16/3}$.
23. *Striatoabietites aytugii* (Visscher, 1966) Scheuring, 1970; BSIP Sl. No.14503, $J_{20/4}$.
24. *Falcisporites nuthallensis* Balme, 1970; BSIP Sl. No. 14494, $T_{6/1}$.
25. *Minutosaccus crenulatus* Dolby in Dolby & Balme, 1976; BSIP Sl. No. 14504, $P_{23/1}$.
26. *Infernopollenites simplex* Kumaran & Maheshwari, 1980; BSIP Sl. No. 14489, $R_{49/1}$.
27. *Podocarpidites grandis* Sah & Jain, 1965; BSIP Sl. No. 14488, G_{26}.

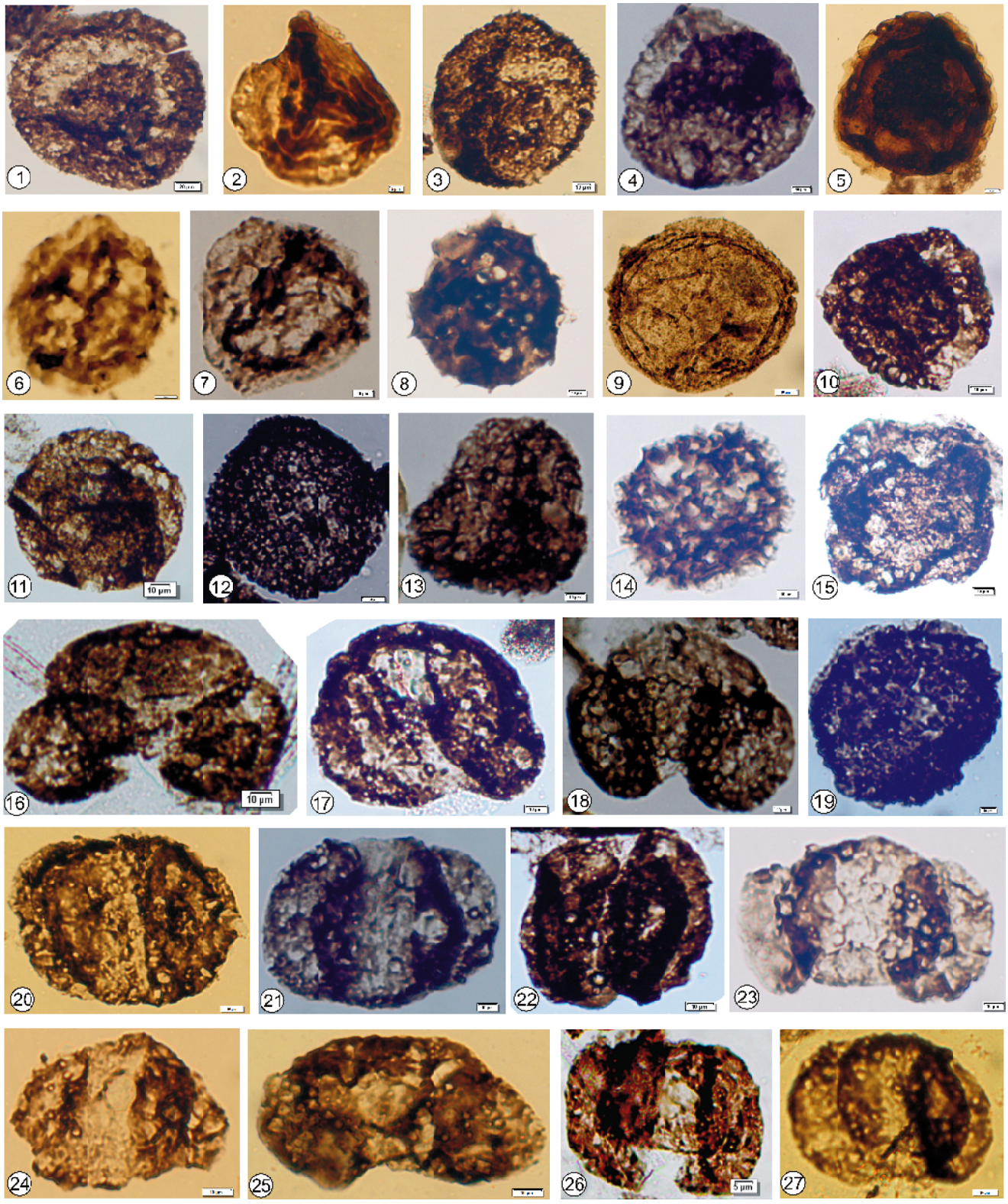
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PLATE 2

(Upadhyay *et al.,* 2004). Occurrence of reworked late Permian (Tatarian) and early Triassic (Scythian) palynomorphs in the Oligo-Miocene sediments of Tharumsa Formation suggests that the late Permian/early to late Triassic palynomorphs bearing older sediments were deposited within the leading passive edge of the Indian Plate, i.e. Zanskar Range and Lamayuru Complex (Upadhyay & Sinha 1998). These sediments have been eroded and redeposited into the Indus Suture trench-subduction complex (Fig. 5).

CONCLUSIONS

The Oligo-Miocene spores and pollen grains recorded in the Tharumsa Formation indicate that the deposition took place under fluvio-lacustrine conditions. An assemblage of spores of *Striatriletes (= Ceratopteris*), algal coenobia of *Pediastrum* (Fig . 6), zygospores of *Lecaniella*, *Aplanosporites* sp. fungal fruiting bodies *Glomus* spp. and gyrogonites of *Chara* indicates that the sediments were deposited in a relatively high energy braided multi-channel fluvial system.

The occurrence of rich and diversified assemblage of reworked early to late Permian and late Triassic palynomorphs is significant in the interpretation of erosion, transportation and re-deposition of pre-existing Gondwanic deposits, which were situated far away from the accommodation site.

During the collision of Indian and Asian plates, a large area of Indian continental margin was subducted. This process resulted in the displacement and erosion of pre-existing rocks, which were transported to the distant places. This phenomenon was more prevalent in Himalayan belts. The erosion of older sequences, their transportation and redeposition in younger horizons are recognized by their fossil contents. Occurrence of reworked Gondwanic palynomorphs is common in the northwest Ladakh and adjacent Himalaya symbolizing tectonic upliftment, erosion of pre-existing rocks (possibly from the Zanskar Platform and Lamayuru Complex) and their transportation to various depositional sites. The presently recorded reworked Gondwanic palynomorphs are closely comparable to the early to late Permian and late Triassic palynoflora recorded by Upadhyay *et al.* (2004) and Ram-Awatar (2008).

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