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Scale leaves from the Barakar Formation of Satpura Gondwana Basin, Madhya Pradesh, India

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ABSTRACT

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Morphological and taxonomic features of dispersed sterile scale leaves collected from the Barakar Formation of Pench, Kanhan and Pathakhera coalfields of Satpura Gondwana Basin, Madhya Pradesh are described. The scale leaves are normally described as morphological types without their assignment to taxonomic status. Due to this practice, the identity and significance of the scale leaves have gone astray in the *Glossopteris* flora. The presence of large number of sterile scale leaves with different morphological features in the present assemblage has helped to discuss their structure, nature and affinity. The scale leaves have been assigned to different genera and species namely *Pantolepis indica* gen. *et* sp. nov., *Penchiolepis gondwanensis* gen. *et* sp. nov., *Penchiolepis indica* sp. nov., *Surangelepis ambarai* gen. *et* sp. nov., *Surangelepis elongatus* sp. nov. and *Utkaliolepis indica* Tiwari *et al.* 2009.

Key-words—Scale leaves, Barakar Formation, Early Permian, Satpura Gondwana Basin.

सतपुड़ा गोंडवाना द्रोणी, मध्य प्रदेश, भारत के बराकार शैलसमूह से प्राप्त शल्क पत्र

ए.के. श्रीवास्तव एवं दीपा अग्निहोत्री

सारांश

सतपुड़ा गोंडवाना द्रोणी, मध्य प्रदेश मे पेंच, कन्हान एवं पाथारवेरा कोयलाक्षेत्रों के बराकार शैलसमूह से संगृहीत परिक्षिप्त अनुर्वर शल्क पत्रों के आकारिकीय एवं वर्गिकीय लक्षण वर्णित किए गए हैं। सामान्यतः शल्क पत्र आकारिकीय प्रकारों के रुप में वगिर्कीय स्थितिनिर्धारित किए बिना वर्णित किए जाते हैं। इस प्रक्रिया की वजह से *ग्लोसोप्टेरिस* वनस्पति-जात में शल्क-पत्रों की पहचान एवं महत्ता भटकी हुई है। मौजूदा समुच्चय में भिन्न आकारिकीय लक्षणों सहित बड़ी संख्या में अनुर्वर शल्क पत्रों की विद्यमानता ने उनकी संरचना, प्रकृति एवं बंधुता की चर्चा में मदद की है। यहां वर्णित शल्क पत्र विविध वंश एवं जाति नामतः *पंतोलेपिस इंडिका* वंश एवं जाति नवम, *पेंचियोलेपिस गोंडवानेन्सिस* वंश एवं जाति नवम, *पेंचियोलेपिस इंडिका* जाति नवम, *सुरंगेलेपिस अम्बाराई* आदि वंश एवं जाति नवम, *सुरंगेलेपिस एलांगेटस* जाति नवम एवं *उत्कालियोलेपिस इंडिका* तिवारी आदि 2009 में नियत की गई हैं।

संकेत-शब्द—शल्क पत्र, बराकार शैलसमूह, प्रारंभिक पर्मियन, सतपुड़ा गोंडवाना द्रोणी।

Escamas foliares da Formação Barakar da Bacia Gondvânica de Satpura, Madhya Pradesh, Índia

RESUMO

Aqui estão descritas características morfológicas e taxonômicas de escamas foliares estéreis, dispersas, coletadas nos hulhíferos Pench, Kanhan e Pathakhera da Formação Barakar, da bacia gondvânica de Satpura, estado de Madhya. As escamas foliares são normalmente descritas como tipos morfológicos sem seu posicionamento taxonômico. Devido a esta prática, a identidade e importância destas têm sido descartadas na flora de Glossopteris. A presença de grande número de

escamas foliares estéreis com diferentes padrões morfológicos na presente assembléia tem ajudado na discussão da sua estrutura, natureza e afinidade. As escamas foliares aqui descritas foram designadas em diferentes gêneros e espécies chamados de *Pantolepis indica* gen. *et* sp. nov.**,** *Penchiolepis gondwanensis* gen. *et* sp. nov.*,* *Penchiolepis indica* sp. nov.*, Surangelepis ambarai* gen. *et* sp. nov.**,** *Surangelepis elongatus* sp. nov. and *Utkaliolepis indica* Tiwari *et al.* 2009.

Palavras-chave—Escamas foliares, Formação Barakar, Eopermiano, Bacia Gondvânica Satpura.

INTRODUCTION

Fossil scale leaves are commonly distributed in *Glossopteris* flora and are known from almost all the geologic formations of Lower Gondwana. However, they are commonly distributed in the Late Permian sequences of Raniganj and Kamthi formations (Banerjee, 1984; Chandra & Tewari, 1991; Tewari, 2007; Tiwari *et al.*, 2009). The association of different types of scale leaves with different types of male and female fructifications of glossopterids indicates their protective nature. However, the occurrence of isolated and detached scales without the mark of fertile features suggests their sterile nature. They are possibly attached to axis in association with foliage leaves (Mc Loughlin, 2011).

Feistmantel (1880, 1881) for the first time described scale leaves from Lower Gondwana sediments of India under the name *Squama*. Later Zeiller (1902), Arber (1905), Seward and Sahni (1920), Walton (1929), Archangelsky (1958), Plumstead (1962), Lacey *et al.* (1975), Chandra and Surange (1977a, b), Banerjee (1984), Anderson and Anderson (1985), McLoughlin, *et al.* (2005), Srivastava (1992), Tewari (2007) and Tiwari *et al.* (2009) reported a variety of scale leaves from Gondwana sediments of India, Australia, South Africa, Argentina and Brazil. Some scale leaves have been considered as the protective device for glossopterid fructifications. Banerjee (1979) has described scale leaves possessing ovule or sporangia– like structures.

Surange and Chandra (1973a, b, c, 1974a, b) reported scale leaves in attachment with the fructifications of *Eretmonia*, *Glossotheca*, *Partha*, *Denkania*, *Lidgettonia*, *Dictyopteridium*, *Plumsteadiostrobus* and *Venustostrobus.* These authors also described the cuticular features of scale leaves under the new genus and species *Scirroma angusta* and *Scirroma ventilebra* (Chandra & Surange, 1977b).

A variety of sterile scale leaves are discovered in dispersed condition from different coalfields of Satpura Gondwana Basin, Madhya Pradesh. The nature and morphological features of the scale leaves are quite diverse. Based on these morphological features and in order to maintain their taxonomic identity, the scale leaves have been assigned to different genera and species.

GEOLOGICAL SETTING

Satpura Gondwana Basin is situated in Madhya Pradesh, central India between 22°06' -22°28' N latitude and 77°48'-

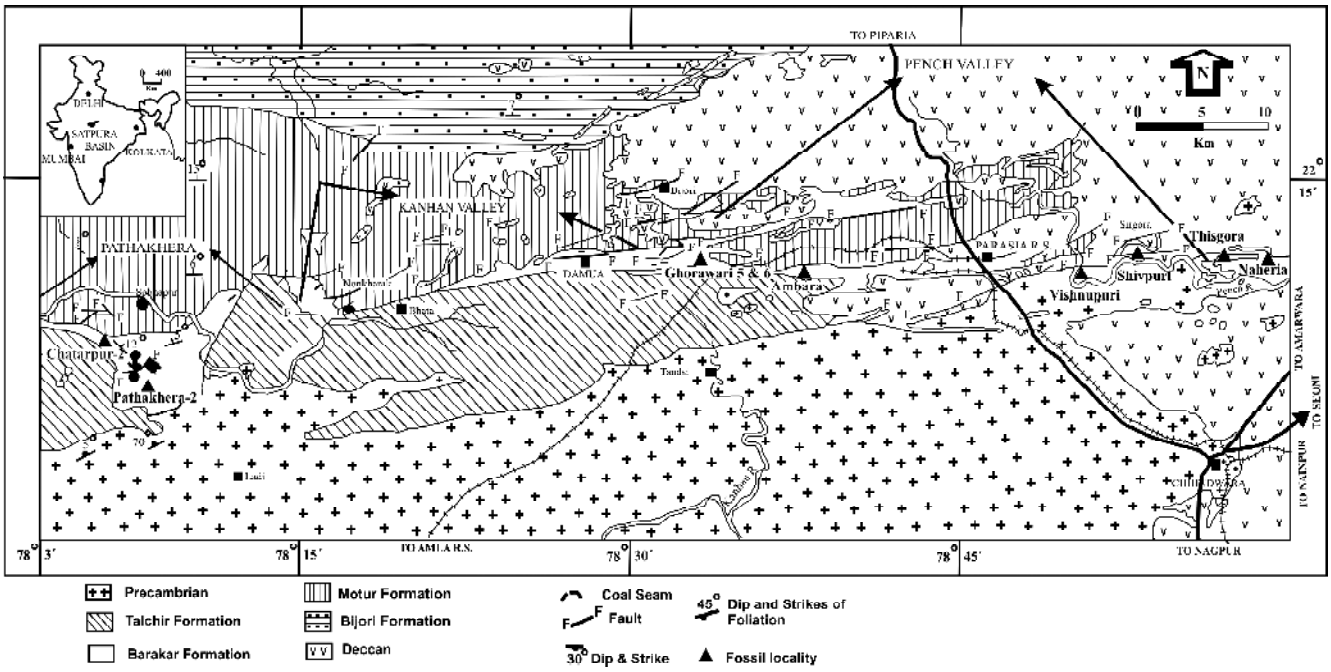
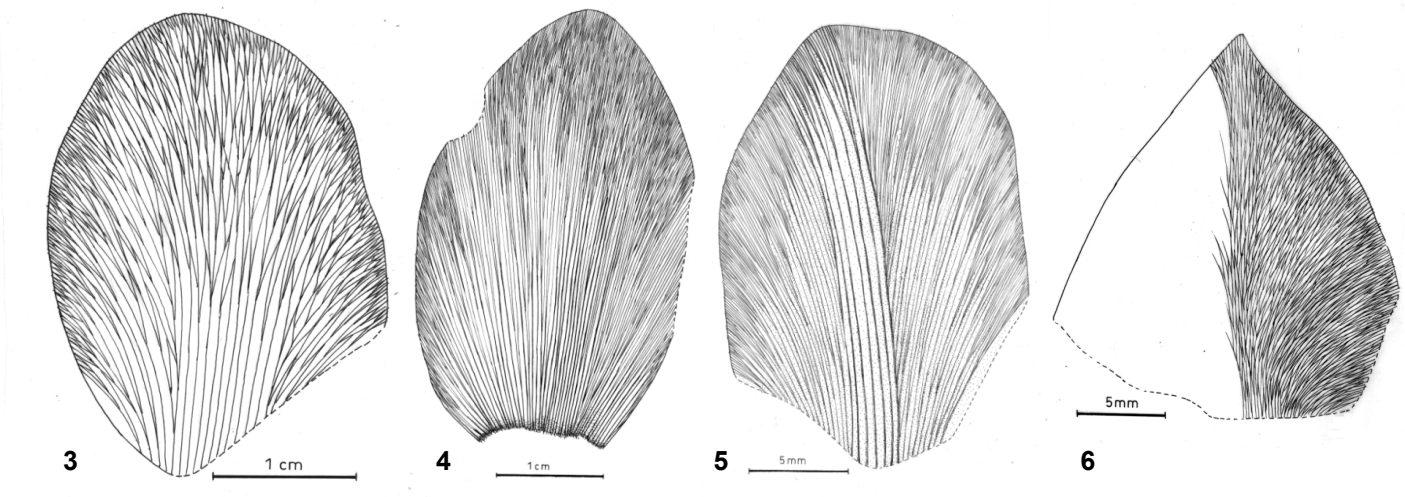


Fig. 1—Geological map of Satpura Gondwana Basin showing fossil localities (after Singh & Shukla, 2004).

FORMATION		LITHOLOGY	THICKNESS	AGE
UPPER GONDWANA	Bagra	Conglomerates, pebbly sandstone, red mudstone; abundant calcareous nodules	500 m	Jurassic (?)
	----------unconformity----------			
	Denwa	Red mudstone and mudstone alternation; calcareous mudstone	300-450 m	Anisian
	Pachmarhi	Very coarse pebbly sandstone with minor grey/red mudstone. Multi- stored sandstone with large compound bedforms	500-800 m	Lower Triassic
---------- disconformity ----------				
LOWER GONDWANA	Bijori	Fine to very coarse sandstone alternate with carbonaceous shale and thin coal bed. Abundant plant impressions, roots and wave-generated structures	800 m	Upper Permian (Kazanian-Tatarian
	Motur	Thick red mudstone-dominated succession with embedded lenses and sheets of medium- to very coarse-grained sandstone; mudstone may be white, green or purple or dark grey; silicified wood fossils common. Sandstone to mudstone ratio varies from 1:10 to 3:1. Cross-beds abundant in sandstones; calcareous nodules of pedogenic origin typify red mudstone	330-480 m	Lower Permian (Ufimian-Kazanian)
	Barakar	Quartzofelsepathic, very coarse to medium sandstone, three major coal seams and associated carbonaceous shales interlayer with sandstone in the upper part of the Formation. Contact with Motur Fm. sharp to gradational. Decimetre-scale cross-beds typical of sandstone; wave-ripple and parallel lamination common in coal-shale units.	140-225 m	Lower Permian (Artinskian)
	Talchir	Boulder- pebble, conglomerates, pebbly sandstone & khaki green shale	100-250 m	Lower Permian (Artinskian)
----------unconformity----------				
Gneisses, quartzites, granites, etc.			Precambrian	

Fig. 2—The stratigraphic succession of the Satpura Gondwana Basin (modified after Raja Rao, 1983).

78°53'E longitude (Fig. 1). The basin is 200 km long and 60 km wide and covers an area of 12000 km^2. It extends in the south of Narmada plains of Hoshangabad and includes the hilly region of southern Hoshangabad, northern Chhindwara and north-eastern Betul (Raja Rao, 1983). On the basis of occurrence of coal, the area has been divided into 3 major coalfields namely Pench, Kanhan and Pathakhera. Lower Gondwana sediments of Satpura Gondwana Basin are represented by Talchir, Barakar, Motur and Bijori formations, and Upper Gondwana formations of the basin are known as Pachmarhi, Denwa and Bagra (Fig. 2). Precambrian basement rocks are overlain unconformably by the Talchir, Barakar, Motur and Bijori sediments. The contact between the Bijori and the Pachmarhi formations marks the boundary between Lower and Upper Gondwana subdivisions (Srivastava & Agnihotri, 2009). Barakar is the only coal bearing horizon in the area. The Barakar Formation consists of medium to coarse grained sandstone, carbonaceous shales, grey shales and coal seams. On the basis of vertical variations, Raja Rao (1983) divided the Barakar Formation into two parts-the lower member shows absence of thick band of coal, it consists of fine to medium grained sandstones and shows a paucity of shale and siltstone interbands, whereas, the upper member is characterized by the development of workable coal seams, and it comprises more coarse grained sandstone units than the lower member.



Figs 3-6—3. *Pantolepis indica* gen. *et* sp. nov. 4. *Penchiolepis gondwanensis* gen. *et* sp. nov. 5. *Penchiolepis indica* sp. nov. 6. *Utkaliolepis indica* Tiwari *et al.* 2009.

MATERIAL AND METHOD

Scale leaves have been collected from the Barakar Formation of Shivpuri, Vishnupuri, Thisgora and Naheria coal mines of Pench Valley Coalfield; Ambara and Ghorawari coal mines of Kanhan Valley Coalfield and Chattarpur-2 and Pathakhera-2 mines of Pathakhera Coalfield of Satpura Gondwana Basin (Fig. 1). The scale leaves are preserved in the form of impressions on the carbonaceous shales and grey sandstone of the Barakar Formation. The morphological features of scale leaves namely size, shape, apex, base and nature of veins were examined under low power binocular Olympus SZH using reflected light at the angle of 40° to 60° and finer details of the specimens were examined at high resolution after soaking the material in xylol. All the specimens are deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow, India.

SYSTEMATICS

Genus—PANTOLEPIS gen. nov.

Type species—*Pantolepis indica* gen. *et* sp. nov.

Generic Diagnosis—Dispersed, sterile scale leaf, oblanceolate in shape, obtuse apex, base narrow, veins arise from base, median veins thick, dichotomize and anastomose frequently to form narrow, elongate, hexagonal meshes in middle part and shorter, squarish meshes near the margin of leaf.

Generic Comparison—Pantolepis gen. nov. is comparable with the scale leaf of *Plumsteadiostrobus*-type glossopterid fructification described by Chandra and Surange (1977a, Text figs 6a, 7a) in having similar obtuse apex and venation pattern but latter differs with present leaf in having elliptic-ovate shape. Scale leaves of *Plumsteadiostrobus*-type are fertile in nature and found in attachment with seed, whereas, *Pantolepis* gen. nov. is a sterile scale leaf and there is no evidence of attached seeds or sporangia.

Pantolepis gen. nov. is comparable with *Utkaliolepis indica* described by Tiwari *et al.* (2009) in having sterile nature of scale leaf with obtuse apex, absence of midrib, presence of frequent dichotomizing and anastomosing veins. However, *Pantolepis* gen. nov. differs from *Utkaliolepis indica* in having oblanceolate shape, comparatively narrower base and narrow, elongate, hexagonal meshes near the base, which become smaller and open near the margin. In *Utkaliolepis indica* meshes are wide and elongate in shape throughout the leaf.

Etymology—The genus is instituted after the name of renowned palaeobotanist Late Prof. D.D. Pant, Botany Department, University of Allahabad, Allahabad.

Pantolepis indica gen. *et* sp. nov.

(Pl. 1.1, 1.2; Fig. 3)

Holotype—BSIP Specimen No. 39979 with counterpart 39980.

Specific Diagnosis—Detached sterile leaf, shape oblanceolate, apex obtuse, base narrow, margin entire; veins arise from base, uniformly thick, form narrow, elongate, hexagonal meshes in middle part and shorter, open, polygonal meshes near margin of leaf, density of veins is higher near margin in comparison to the lower-middle part of leaf.

Occurrence—Thisgora Open Cast Mine, Pench Valley Coalfield; Satpura Gondwana Basin, Madhya Pradesh.

Horizon—Barakar Formation.

Age—Early Permian.

Description—Well preserved detached scale leaf is preserved with part and counterpart in the collection. Leaf is oblanceolate in shape, 1.6 cm long and 1.1 mm broad, apex obtuse, base tapering. 11 veins arise from the base, dichotomize and anastomose to form narrow, elongate and hexagonal meshes in the middle part and smaller, open and polygonal meshes near the margin of the leaf. Meshes are frequent in median region as well as in marginal part of the leaf, are 2.5-3 mm long and 0.4-0.5 mm broad in the middle and 1-1.8 mm long and 0.3-0.6 mm broad near the margin of the leaf. Density of veins is 16-19 veins/cm in middle part and 20-34 veins/cm near the margin.

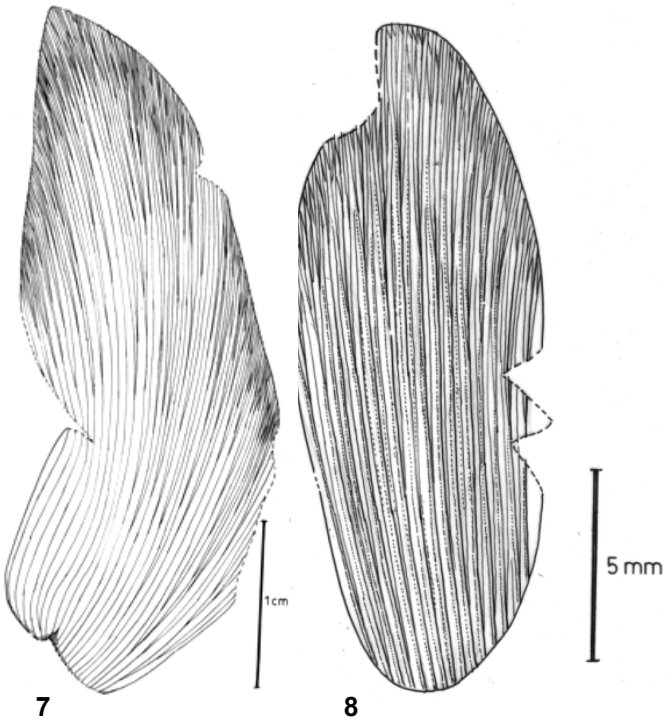
Comparison and Discussion—Pantolepis indica gen. *et* sp. nov. is comparable with the scale leaf of glossopterid fructification *Plumsteadiostrobus ellipticus* described by Chandra and Surange (1977a) from the Raniganj Formation of Raniganj Coalfield, West Bengal in having obtuse apex, frequently dichotomizing and anastomosing veins, narrow, elongate meshes in middle part of leaf and broad, shorter meshes near the margin, but present leaf differs from *P. ellipticus* in having elliptic shape and prominent veins in median region. Present specimen also compares with Scale leaf gen. A described by Anderson and Anderson (1985, Pl. 143, figs 14, 15, 16) in having similar shape and nature of apex and base, but in scale leaves, described by Anderson & Anderson (1985) median veins are distinctly thick and coarser in nature in comparison to *Pantolepis indica* which shows uniformly thin veins throughout the lamina. Anderson and Anderson (1985) described these scale leaves without any generic and specific name. Present leaf is also comparable with *Utkaliolepis indica* described by *Tiwari et al.* (2009, Pl. 2, fig. 3) in having similar obtuse apex, absence of midrib, sterile nature, and in having frequently dichotomizing and anastomosing veins, but *Pantolepis indica* sp. nov. differs in having oblanceolate shape and narrow, elongate and hexagonal meshes in the lower part and small, open, tetra-hexagonal meshes near the margin of the leaf. *Utkaliolepis indica* shows typical ovoid shape with large, elongate meshes.

Genus—PENCHIOLEPIS gen. nov.

Type species—*Penchiolepis gondwanensis* gen. *et* sp. nov.

Generic Diagnosis—Dispersed sterile scale leaf, symmetrical, ovate in shape, apex obtuse and base obtuse-cuneate, margin entire, midrib absent, veins arise from the base, few veins run straight in median region, lateral veins divert at very low angle, veins dichotomize frequently, rarely anastomose to form few meshes near the margin.

Generic Comparison—Penchiolepis gen. nov. is comparable with fertile scale leaf of glossopterid fructification *Eretmonia ovata* described by Surange and Chandra (1974b; Pl. 1, fig. 6; Text-fig. 8) in having ovate shape. However,



Figs 7-8—7. *Surangelepis ambarai* gen. *et* sp. nov. 8. *Surangelepis elongatus* sp. nov.

Penchiolepis gen. nov. is isolated sterile scale leaf characterized by obtuse apex, obtuse-cuneate base and possesses few meshes near the margin of leaf, whereas, the scale leaf of *Eretmonia ovata* shows frequent anastomoses of veins, forming reticulate pattern similar with the venation pattern of vegetative leaf (ironically, it was mentioned as *E. ovoides* by Chandra & Surange, 1977a). Chandra and Surange (1977b) instituted a new genus of scale leaf *Scirroma* on cuticular features and also described a detached scale leaf of *Eretmonia*-type glossopterid fructification. Rhomboidal shaped *Scirroma* scale leaf is distinct from *Penchiolepis* in having frequent meshes, where the meshes are few and confined only to the margin of the leaf. New genus is instituted to accommodate the isolated /dispersed scale leaves without any fertile structure.

Etymology—The genus is named after the Pench Valley Coalfield of Satpura Gondwana Basin, Madhya Pradesh.

Penchiolepis gondwanensis gen. *et* sp. nov

(Pl. 1.3, 1.6; Fig. 4)

Holotype—BSIP Specimen No. 39981.

Occurrence—Ambara Open Cast Mine, Kanhan Valley Coalfield, Chhindwara District, Satpura Gondwana Basin, Madhya Pradesh.

Horizon—Barakar Formation.

Age—Early Permian.

Specific Diagnosis—Ovate shaped sterile scale leaf showing obtuse apex, obtuse-cuneate base, margin entire, midrib absent, veins arise from base, median region occupied by 2-3 parallel veins, lateral veins divert at the angle of less than 10° and reach straight to the margin, frequently dichotomize and anastomose rarely to form 3-5 mm long and 0.2-0.3 mm broad meshes near margin.

Description—Well preserved, complete scale leaf impression is present in the collection. Leaf is 2.4 cm long, 1.5 cm broad, ovate in shape with obtuse apex, obtuse-cuneate base and entire margin. Midrib is absent. 12 prominent parallel veins emerge from the base, 2-3 veins run straight in the median region, whereas, lateral veins divert at very low angle (less than 10°) and reach upto the margin of the leaf. Median veins show convergence near the apex. During the course, these veins dichotomize frequently but anastomose rarely near the margin to form few narrow, elongate and hexagonal, 3-5 mm long and 0.2-0.3 mm broad meshes. Density of veins is 15-18 veins/cm in the lower part and 20-22 veins/cm near the margin. The leaf is attributed to sterile scale leaf in the absence of attached seeds and sporangia.

Comparison and Discussion—*Penchiolepis gondwanensis* gen. *et* sp. nov. is comparable with the scale leaf of *Eretmonia ovata* Chandra and Surange (1977a, Pl. 1, fig. 6; Text-fig. 1 D) in having ovate shape, absence of midrib and presence of meshes, but *Eretmonia ovata* Surange and Chandra (1974b) shows long, pointed acute apex, whereas, present specimen shows distinct obtuse apex. *Eretmonia ovata* Chandra and Surange (1977a) also differs from the present specimen in having different venation pattern. In *Eretmonia ovata* Surange and Chandra (1974b), lateral veins divert at about 30°-40° with frequent anastomosis, whereas, in the present specimen lateral veins divert at very low angle (less than 10°) with rare anastomosis confined towards the margin.

Penchiolepis gondwannesis gen. *et* sp. nov. is also comparable with the Scale Leaf gen. C described by Anderson and Anderson (1985, Pl. 145, figs 11, 12, 13) from Vereeniging, South Africa in having ovate shape and low angle of diversion of lateral veins. However, anastomosis is completely absent in the scale leaves described by Anderson and Anderson (1985), whereas, in the present specimen few meshes are present near the margin. Anderson and Anderson (1985) did not give any generic and specific name to the specimens. *Utkaliolepis indica* described by Tiwari *et al.* (2009, Pl. 2, fig. 3: Text-fig. D) from the Kamthi Formation of Hinjrida Ghati Section, Handappa, Orissa is comparable in having ovate shape, obtuse apex but differs in possessing more divergent lateral veins and frequent occurrence of meshes throughout the leaf.

Penchiolepis indica sp. nov.

(Pl. 2.1; Fig. 5)

Holotype—BSIP Specimen No. 39982.

Diagnosis—Dispersed sterile scale leaf, broad, ovate in shape, apex obtuse, base rounded, median region occupied by 5-6 prominent parallel veins, lateral veins arise from the base and divert at an angle of 25°-30°, frequently dichotomize but anastomose rarely to form few narrow, elongate, hexagonal meshes near the margin.

Occurrence—Kanhan Valley Coalfield: Ambara Open Cast Mine, Ghorawari incline mine (5 and 6).

Horizon—Barakar Formation.

Age—Early Permian.

Other specimen—BSIP Specimen No. 39983.

Description—Two well preserved, complete leaf impressions are present in the collection. Size of leaves ranges from 2.5-3.4 cm in length and 1.6-2.2 cm in breadth. Well preserved leaf is 2.5 cm long and 1.6 cm broad with ovate shape, obtuse apex and rounded base. Median region is represented by 5-6 thick and prominent median veins, which run parallel to each other and reach upto the margin. Lateral veins arise from the base, divert at an angle of 25°-30° and dichotomize frequently, but they anastomose rarely near the margin and form few narrow, elongate, hexagonal, 3-5 mm long and 0.4-0.5 mm broad meshes. Density of veins is 14-18 veins/cm in the lower part and 18-20 veins/cm near the margin.

Comparison and Discussion—*Penchiolepis indica* sp. nov. differs from the type species *Penchiolepis gondwanensis* sp. nov. in having more divergent lateral veins. In *Penchiolepis gondwanensis* sp. nov. lateral veins divert at less than 10°, whereas, in *P. indica* they divert at 25°-35°. Thick parallel median veins are present in *P. indica* sp. nov., are absent in *P. gondwanensis*. The base of *P. gondwanensis* gen. *et* sp. nov. is obtuse-cuneate, whereas, it is distinctly rounded in *P. indica*.

Penchiolepis indica sp. nov. is comparable with the scale leaf of *Eretmonia ovata* described by Surange and Chandra (1974b, Pl. 1, fig. 4; Text-fig 8) in having similar ovate shape,

PLATE 1 →

1. *Pantolepis indica* gen. *et* sp. nov. showing complete leaf. BSIP Specimen No. 39979.
2. Counterpart of *Pantolepis indica* gen. *et* sp. nov. BSIP Specimen No. 39980.
3. Enlargement of venation pattern of leaf *Pantolepis indica* gen. *et* sp. nov.
4. Enlargement of venation pattern of *Penchiolepis gondwanensis* gen. *et* sp. nov.
5. *Utkaliolepis indica* Tiwari *et al.,* 2009 showing the complete leaf. BSIP Specimen No. 39987.
6. *Penchiolepis gondwanensis* gen. *et* sp. nov. showing complete leaf. BSIP Specimen No. 39981.

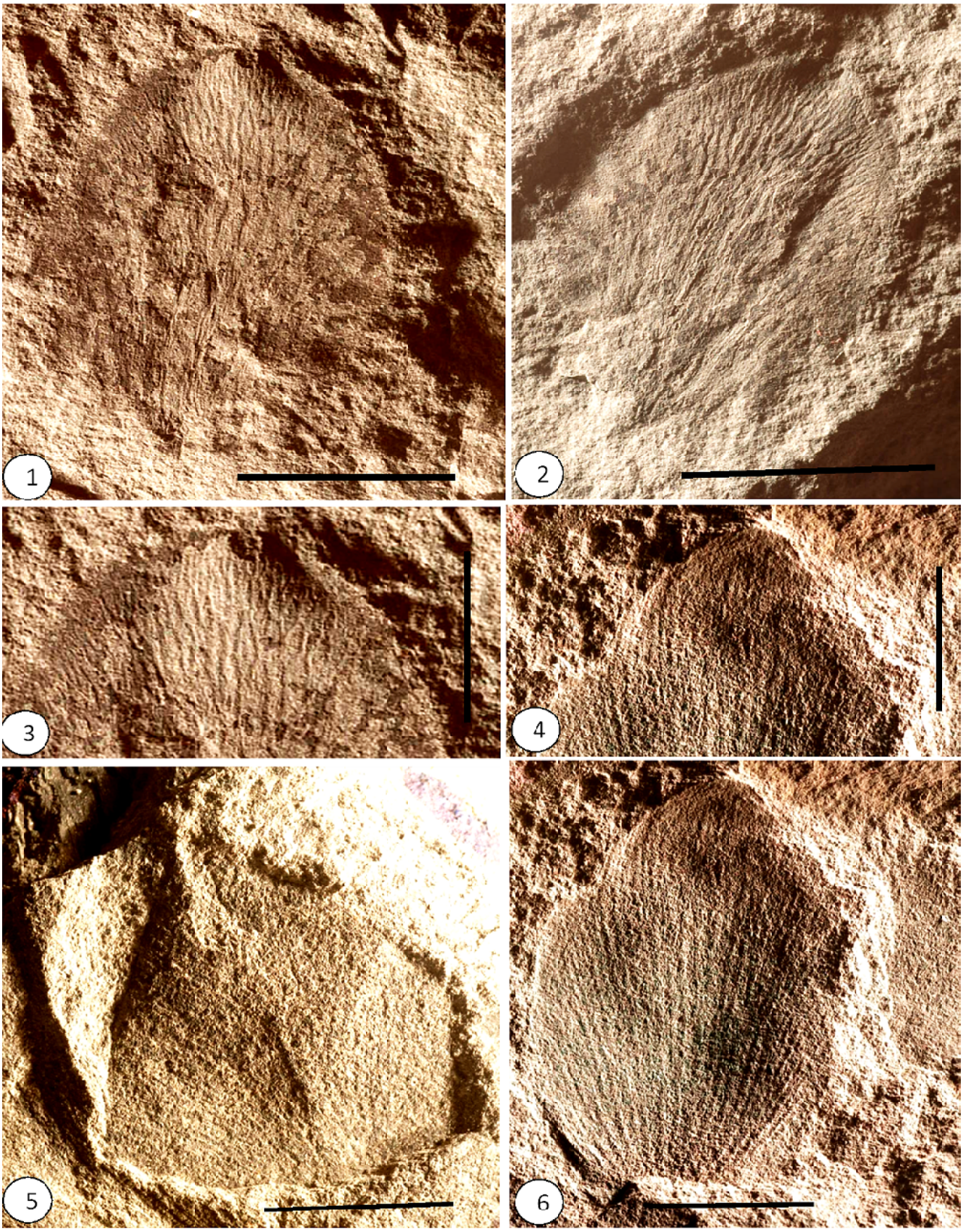


PLATE 1

rounded base, thick median veins and angle of divergence of lateral veins (25°-30°), but present specimens differ from the scale leaf of *E. ovata* in having obtuse apex. *Eretmonia ovata* shows acute apex. Surange and Chandra (1974b) described the species *Eretmonia ovata* for the scale leaf in attachment with sporangia, whereas, *Penchiolepis indica* sp. nov. is detached sterile scale leaf without fertile structure.

Specimens show some resemblance with *Utkaliolepis indica* instituted by Tiwari *et al.* (2009, Pl. 2, fig. 3; Text-fig. 1 D) in having similar ovate shape, obtuse apex, broad base, more divergent lateral veins and absence of attached seed or sporangia like structures, but it differs from *Penchiolepis. indica* in having frequent anastomosis and presence of meshes throughout the lamina. *Penchiolepis indica* sp. nov. shows rare anastomosis and fewer meshes near the margin.

Genus—SURANGELEPIS gen. nov.

Type species—***Surangelepis ambarai*** gen. *et* sp. nov.

Generic Diagnosis—Isolated, dispersed sterile scale leaf, oblong-ovate in shape, apex acute, base rounded, margin entire, veins emerge from the base, median veins run parallel, lateral veins divert at 5°, dichotomize frequently, rarely anastomose to form few meshes near the margin.

Generic Comparison—Surangelepis gen. nov. is comparable with the scale leaf of glossopterid fructification *Dictyopteridium feistmantelii* described by Chandra and Surange (1976, Pl. 1, figs 1, 2, Pl. 2, fig. 5) in having similar oblong-ovate shape with acute apex and broad base However, *Surangelepis* gen. nov. differs with the scale leaf of *Dictyopteridium feistmantelii* in having distinct venation pattern. In *Surangelepis*, median veins run parallel, lateral veins divert at very low angle and veins rarely anastomose to form meshes, whereas, in the scale leaf of *Dictyopteridium feistmantelii*, lateral veins divert at about 30°-35°, frequently dichotomize and anastomose to form meshes throughout the leaf. *Surangelepis* gen. nov. represents isolated scale leaf without reproductive structure, whereas, the scale of *Dictyopteridium feistmantelii* represents a fertile scale in attachment with glossopterid fructification.

Etymology— The genus is named after renowned palaeobotanist Late Prof. K.R. Surange, former Director of Birbal Sahni Institute of Palaeobotany, Lucknow and Maharashtra Association for the Cultivation of Sciences, Pune.

Surangelepis ambarai gen. *et* sp. nov.

(Pl. 2.3-2.5; Fig. 7)

Holotype—BSIP Specimen No. 39984.

Specific Diagnosis—Sterile scale leaf, oblong-ovate in shape, margin entire, median veins run parallel, lateral veins divert at very low angle (5°) and form narrow, elongate, hexagonal meshes only near the margin of leaf.

Occurrence—Ambara Open Cast Mine, Kanhan Valley Coalfield, Chhindwara District, Satpura Gondwana Basin, Madhya Pradesh.

Horizon—Barakar Formation.

Age—Early Permian.

Etymology—The species is named after the locality Ambara Open Cast Mine, Pench Valley Coalfield.

Description—Well preserved, complete leaf impression is present in the collection. The base of the leaf is slightly folded. Leaf is 4.1 cm long and 1.3 cm broad at its widest, oblong-ovate in shape, apex acute, base rounded, midrib absent, margin entire. 14 thick prominent veins emerge from the base of leaf. 4-5 median veins run parallel, reach upto the apex. Lateral veins divert at 5°, dichotomize and anastomose rarely to form few narrow, elongate, hexagonal meshes measuring 4-6 mm in length and 0.5-0.6 mm in width near the margin. Density of veins is 18-22 veins/cm throughout the lamina. Leaf is preserved in twisted manner.

Comparison and Discussion—Surangelepis ambarai gen. *et* sp. nov. resembles the scale leaf of *Dictyopteridium feistmantelii* described by Chandra and Surange (1976, Pl. 1, figs 1, 2, Pl. 2, fig. 5) from the Raniganj Formation of Raniganj Coalfield, West Bengal, which is attached with the leaf of *Glossopteris tenuifolia* Pant & Gupta in having similar oblong-ovate shape, acute apex and rounded base. However, *Surangelepis ambarai* sp. nov. is instituted for isolated scale leaf without fertile structure and also differs in having distinct venation pattern. In scale leaf of *Dictyopteridium feistmantelii* lateral veins divert at an angle of 30°-35°, frequently dichotomize and anastomose to form meshes throughout the lamina, whereas, in *Surangelepis ambarai* sp. nov., lateral veins divert at an angle of 5°, dichotomize frequently, but rarely anastomose to form meshes. Meshes are very few and present only near the margin.

Present specimen compares well with the scale leaves described by Anderson and Anderson (1985, Pl. 145, figs 8, 9,

PLATE 2 

1. *Penchiolepis indica* sp. nov. showing complete leaf. BSIP Specimen No. 39982.
2. *Surangelepis elongatus* sp. nov. showing complete leaf. BSIP Specimen No. 39985.
3. *Surangelepis ambarai* gen. *et* sp. nov. showing complete leaf. BSIP Specimen No. 39984.
4. Enlargement of *Surangelepis ambarai* gen. *et* sp. nov. to show the acute apex and details of venation pattern.
5. Enlargement of venation pattern of lower part of *Surangelepis ambarai* gen. *et* sp. nov.

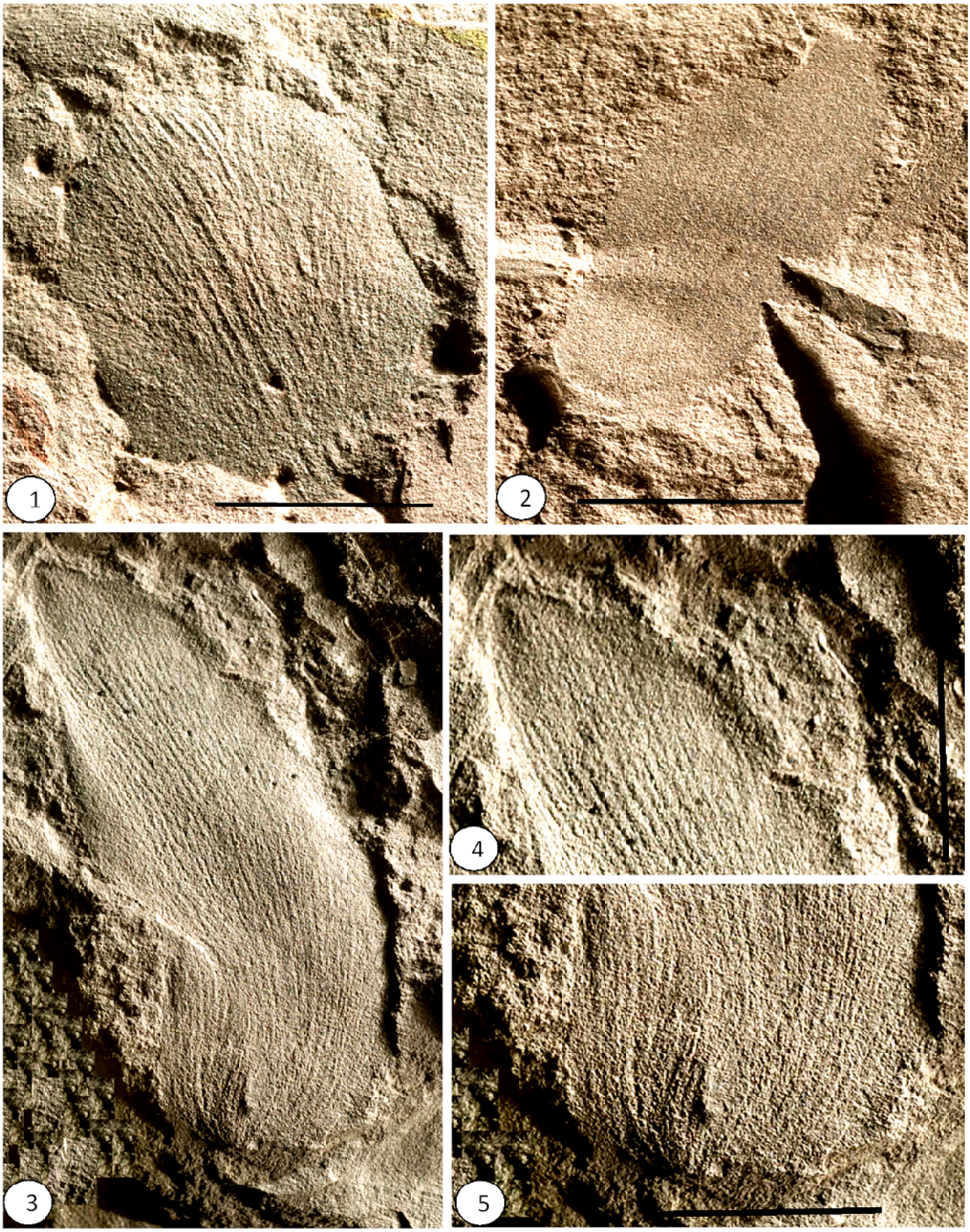


PLATE 2

15, 16) from Vereeniging as Scale leaf gen. C in showing similar shape, acute apex, absence of midrib and divergence of lateral veins but in Scale leaf gen. C, veins never anastomose. Present specimen is also comparable with the sterile scale leaf of *Handapiolepis parijaii* described by Tiwari *et al.* (2009, Pl.1, fig. 4, Pl. 2, fig. 1) from the Kamthi Formation of Hinjrida Ghati Section, Handappa Village, Orissa in having oblong shape, acute apex and absence of midrib. *Handapiolepis parijaii* is distinct in possessing frequent meshes throughout the lamina.

Surangelepis elongatus sp. nov.

(Pl. 2.2; Fig. 8)

Holotype—BSIP Specimen no. 39985 and counterpart 39986.

Diagnosis—Isolated, dispersed scale leaf, oblong-ovate in shape, obtuse apex, rounded base, midrib absent, thin, semi-parallel, closely spaced veins emerge from base and spread towards margin, veins do not arch, dichotomize, curve gently to meet the margin, anastomose only near the margin, very fine striations are present in between the veins.

Occurrence—Naheria underground mine, Pench Valley Coalfield, Chhindwara District, Satpura Gondwana Basin, Madhya Pradesh.

Horizon—Barakar Formation.

Age—Early Permian.

Description—Well preserved leaf, with counterpart is present in the collection. Leaf is 1.9 cm long and 0.7 cm broad, oblong-ovate in shape, apex obtuse, base rounded, midrib absent, margin entire. 10-12 veins emerge from the base, veins crowded, run parallel to each other, do not arch, but curve smoothly to meet the margin. During the course they dichotomize frequently, but anastomose rarely. Very few meshes are present near the margin. Leaf shows fine striations between the veins. Density of veins is 7-10 veins/5 mm in the lower part and 10-12 veins/5 mm near the margin.

Comparison and Discussion—*Surangelepis elongatus* sp. nov. is comparable with the type species *Surangelepis ambarai* gen. *et* sp. nov. in having similar oblong-ovate shape, rounded base, absence of midrib, parallel veins and rare occurrence of meshes, but differs in its smaller size, (*Surangelepis elongatus* is 1.9 cm long and 0.7 cm broad, whereas, *S. ambarai* is 4.1 cm long and 1.3 cm broad) and having obtuse apex. *Surangelepis. ambarai* shows typical acute apex. Veins also diverge at very low angle in comparison to *S. ambarai*. Besides, the present specimen also shows resemblance with the scale leaves described by Anderson and Anderson (1985, Pl. 145, fig. 14) from Vereeniging, New South Wales, South Africa under Scale Leaf gen. 'C' in having oblong-ovate shape, obtuse apex and absence of midrib, but the Scale Leaf gen. 'C' described by Anderson and Anderson (1985) is distinct in having auriculate base. Additionally, the meshes are absent in Scale Leaf gen.'C'. *Surangelepis elongatus* is comparable with *Nautiyalolepis lanceolata* described by Tiwari *et al.* (2009, Pl. 1, figs 3, 4) in its smaller size and absence of midrib but *N. lanceolata* differs from present specimen in having lanceolate shape, acute apex, more divergent lateral veins with frequent meshes. In the absence of any attached seed or sporangia *Surangelepis elongatus* sp. nov. is considered as sterile scale leaf.

Genus—UTKALIOLEPIS Tiwari *et al.* 2009

Type Species—*Utkaliolepis indica* Tiwari *et al.* 2009

Utkaliolepis indica Tiwari *et al.* 2009

(Pl. 1.5; Fig. 6)

Description—There are four well preserved scale leaves without any fertile structure in the collection. Leaves range in size from 2-3 cm in length and 1.5-3 cm in breadth, sessile, rhomboidal-trianguloid in shape, apex acute, base broad, margin entire, midrib absent. Median region is represented by 2-3 parallel running veins which dichotomize in the apical region, lateral veins also arise from the base, divert at an angle of 30°-40° to meet the margin. During the course, these veins dichotomize and anastomose to form meshes. Meshes are long, narrow, hexagonal, 2-4.5 mm long and 0.2-0.4 mm broad. Density of veins is 10-14 veins/cm in the middle region, 16-18 veins/cm near the margin.

Specimen Nos. —BSIP Specimen Nos. 39987, 39988, 39989, 39990.

Occurrence— Shivpuri Open Cast Mine, Vishnupuri u/g of Pench Valley Coalfield; Chattarpur Mine-2, Pathakhera Mine-2 of Pathakhera Coalfield.

Horizon—Lower Barakar Formation.

Age—Early Permian.

Comparison and Discussion—Present specimen is comparable with *Utkaliolepis indica* described by Tiwari *et al.* (2009, Pl. 2, fig. 5) from the Kamthi Formation of Handappa area, Orissa in having rhomboidal-trianguloid shape, acute apex, broad base and presence of median veins, divergent lateral veins, which dichotomize and anastomose to form frequent meshes throughout the lamina. It is also comparable with *Scirroma angusta* described by Chandra and Surange (1977b; Text-fig. 1 D) from the Raniganj Formation, Raniganj Coalfield, West Bengal in having rhomboidal shape, acute apex and similar venation pattern. However, Chandra and Surange (1977a) instituted the genus and species on the basis of cuticular features, whereas, *Utkaliolepis indica* is known by external morphological features. *Utkaliolepis indica* is comparable with Scale Leaf gen. A described by Anderson and Anderson (1985, Pl. 143, figs 6, 8, 9) from Vereeniging, South Africa in having similar shape, nature of apex, base and

venation pattern. The scale leaves are also comparable with the scale leaf described by McLoughlin *et al.* (2005, fig. 6a) from Dronning Maud land, Antarctica in having rhomboid shape, acute apex, broad base and similar venation pattern.

DISCUSSION

The scale leaves discovered from Satpura Gondwana Basin are essentially different from the known scale leaves of Lower Gondwana in having broad base with closely spaced fine veins. Veins run parallel in *Surangelepis,* whereas, in *Penchiolepis,* the median veins are parallel but lateral veins show arching. Scale leaves of *Pantolepis* are very characteristic in showing almost squarish meshes near the margin and elongate, broad meshes in median region; veins also show slight rippling in central part of leaf. *Utkaliolepis* is known by triangular shaped leaves having parallel veins which form meshes only near the margin of the leaf.

Scale leaves in *Glossopteris* flora have normally been associated with glossoterid fructifications and have found to show concavity or convexity indicating the position of fertile structure (Surange & Chandra, 1975; Chandra & Surange, 1976). Sometimes they have also been described as ovule or sporangia –bearing organ (Banerjee, 1979; Lacey *et al.,* 1975).

Interestingly, none of the scale leaves of the present collection have been discovered in association with fertile structure. The plant fossil assemblage of Satpura Gondwana Basin, is too devoid of scale leaf-bearing glossopterid fructification. Therefore, it is difficult to associate the present scale leaves with glossopterid fructification as suggested by earlier workers. In the absence of any fertile structure in attachment or in association with present scale leaves, they are considered as the sterile part of glossopterids or allied group of plants.

The sterile nature of scale leaves have also been discussed by Pant (1958) and Pant and Chauhan (2000) and they have interpreted the presence of dispersed scale leaves as ordinary protective scales of vegetative bud of glossopterids and suggested that there is no need to consider them as reproductive organ.

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