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Gondwana Biostratigraphy and Hydrocarbon Potential of Purnea Basin, and its correlation with Rajmahal and Bengal Basins

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Abstract

Purnea Basin is a polyhistory sedimentary basin in eastern parts of Bihar, having thick Gondwana succession in the subsurface below Ganga Alluvium and Neogene Siwalik sediments. However, the age of different Gondwanic lithounits encountered in key wells of this basin and their correlation with standard Gondwana units are poorly understood due to very little and inadequate biostratigraphic data.

Present biostratigraphic (palynological) studies on the Gondwana sediments in wells KRD-A (1065-3143m), PRN-A (1223-2844m) and LHL-A (1005-3299m) establishes the recognition of thirteen palynological zones ranging in age from Early Permian (Asselian) to Late Triassic (Carnian) which are closely comparable with the established standard Indian Gondwanic zones. The comparison of recognized zones with established Gondwana zones suggests that the Lower (Permian) as well as Upper (Triassic) Gondwana are fully-developed in the Purnea Basin. The Rajmahal traps and intertrapeans, corresponding to the early synrift event, which are well-developed in adjoining Rajmahal, Galsi and Bengal basins, are absent in this basin. The Neogene Siwalik sediments directly rest over the Gondwana sediments in Purnea Basin, representing a major non-depositional hiatus of ca 187My, spanning from latest Triassic (ca 203Ma) to Early Miocene (ca 16Ma).

The Lower Gondwana (Permian) palynofloras of Purnea Basin, recorded from Karandighi, Salmari, Katihar and Dinajpur formations, closely compare with the palynological assemblages of Talchir, Karharbari, Barakar and Raniganj formations respectively and suggests the absence of Barren Measures or its equivalent sediments in this basin. The Upper Gondwana (Triassic) palynofloras are represented by Early, Middle and Late Triassic assemblages which correlate with the Panchet and Supra-Panchet (Durgapur /Dubrajpur Fm.) assemblages, and indicates the absence of uppermost parts (latest Triassic) of Gondwana succession.

The lithological and biostratigraphic attributes of Gondwana sediments of Purnea, Rajmahal and Galsi basins are almost similar, and located in a large N-S trending Gondwanic graben, referred to as the Galsi-Rajmahal-Purnea Graben. Although, Gondwanas are covered with Late Jurassic-Early Cretaceous Rajmahal traps and intertrappeans beds in Rajmahal, Galsi and Bengal basins, the same are not encounterd in the drilled wells of Purnea Basin. Yet, its presence can not be ruled out since this basin is very close to the Rajmhal Basin.

A fluvial depositional environment is inferred for the entire Gondwana sediments of this basin, except for the basal parts (Karandighi Formation) which palynoflora is associated with marine acritarchs (leiosphaerids), and inferred to be deposited in marginal marine environment corresponding to the Manendragarh/Umaria marine incursion during Early Permian (Asselian-Sakmarian) Talchir sedimentation.

The source-rock and subsidence history data suggest that the Lower Gondwana sediments are with rich TOM and TAI of 2.75+, and were within gaseous window from Middle Triassic to Late Cretaceous.

INTRODUCTION

Purnea Basin is a polyhistory sedimentary basin in the eastern part of Bihar and northern West Bengal, covering about 18000 sq.km. in the districts of Purnea and Kishanganj. Tectonically, it represents the two sedimentary basins. The older one is the North-South trending Gondwanic basin housing Permo-Triassic Gondwana sediments and the younger one East-West trending Ganga Basin having Neogene Siwalik sediments and subrecent Ganga Alluvium (Fig.1). The Purnea Gondwanic Basin occurs below the thick cover of Siwalik sediments in the subsurface (table 1). It is bounded by N-S running two major faults, the western one known as the Bhawanipur Fault and the eastern one as the Kishanganj Fault (Fig.1). The subsurface geological and geophysical data suggest that the Permo-Triassic Gondwana sediments are separated from the overlying Neogene Siwalik sediments with a major regional unconformity, known as the “Main/Siwalik Unconformity”. The Purnea Gondwana Basin also lies north of exposed Rajmahal Basin, and considered to be a part of the Galsi-Rajmahal-Purnea Gondwanic Graben (Prasad and Phor, 2009) [Fig 1]. Lithostratigraphic data from the drilled wells of PRN-A, KRD-A and LHL-A suggest the occurrence of very thick (approx. 2200m) and well-developed Gondwana succession in the subsurface. However, the precise age of different Gondwanic lithounits encountered in the above wells in Purnea Basin and their biostratigraphic correlation with adjoining Gondwana basins have not been attempted due to little and inadequate biostratigraphic data.

In the present work, detailed palynological studies have been undertaken on Gondwana sediments of Purnea Basin encountered in PRN-A, KRD-A and LHL-A wells to determine precise age and depositional environment of different Gondwana units. In addition, recognition unconformities within Gondwana and their span are also estimated alongwith correlation of Gondwana sediments of this basin with those of Rajmahal and Bengal basins to understand Gondwana depositional history of Purnea Basin.

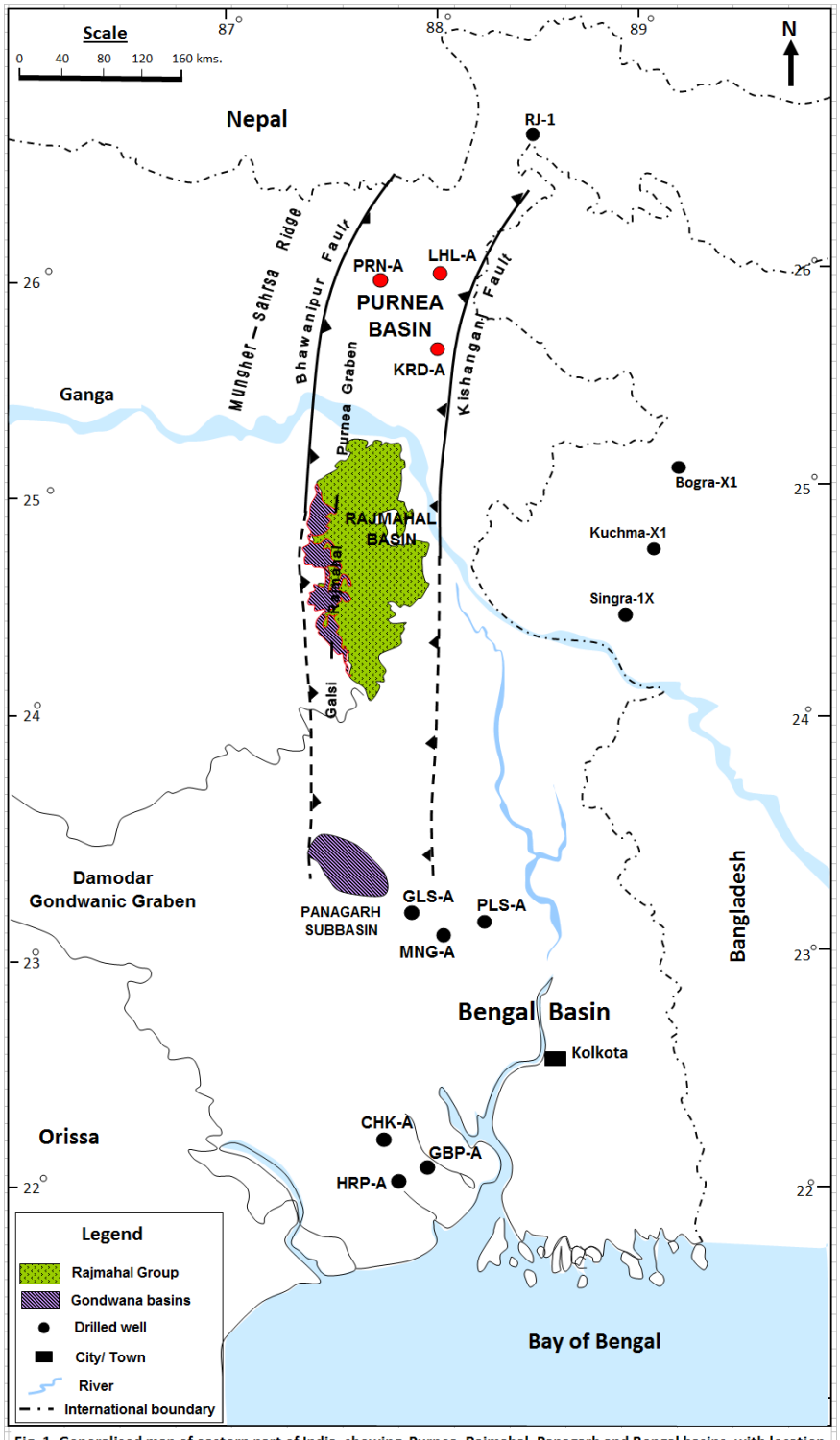

Fig. 1. Generalised map of eastern part of India, showing Purnea, Rajmahal, Panagarh and Bengal basins, with location of studied wells in Purnea Basin and other exploratoary wells with Gondwana succession in adjoining basins

GEOLOGY AND LITHOSTRATIGRAPHY

The Purnea Basin is mainly covered with recent alluvium in the outcrops. However, thick successions of Neogene Siwalik and Permo-Triassic Gondwana occur below the alluvium, wherein Siwalik sediments directly rest over the Gondwana succession with a major unconformity (Table 1). Sediments of Gondwana and Siwalik groups are encountered in all the three exploratory wells, viz. PRN-A, LHA-A and KRD-A, drilled in the Purnea Basin (Table 1). In general, two structural styles corresponding to different modes of tectonics have been recognized in the Purnea Basin (Shukla *et al.*, 1993). The Early phase comprises to Permo-Triassic Gondwana sediments and later phase to the Late Cenozoic (Neogene) Siwalik sediments. Though, the eastern limit of the Purnea Basin is delimited by the Kisanganj Fault (Fig. 1), recent records of Gondwana sediments in the subsurface in northwestern Bangladesh indicated that its eastern limit may be located further east beyond the Kishanganj Fault. Lithologically, Lower Gondwana in Purnea Basin is subdivided into 4 units.

These are Karandighi, Salmari, Katihar and Dinajpur formations from older to younger. The Upper Gondwana is represented by single unit of Lahil Formation (Fig. 2).
The first exploratory well, PRN–A, was drilled in 1964 in the Purnea Basin. Subsequently, two more wells, viz., KRD-A and LHL-A were drilled in 1989–90. Very thick Gondwana sediments (max thickness 2200m in LHL-A) were encountered in all the three wells that rest over the Precambrian basement (Mungher Phyllite Schists/ Chhota Nagpur Granitic Complex, and separated from the overlying Neogene Siwalik sediments by a pronounced regional Siwalik Main Unconformity. Thickness of encountered Gondwana and their depth-intervals in the above drilled wells are shown in Table 1 below.

Table-1: Encountered Gondwana and post-Gondwana Siwalik sediments in drilled wells of Purnea Basin

Group	Formation	Distribution		
		KRD–A	**PRN–A**	**LHL–A**
Siwalik Group	Siwalik Formation	332 – 1065m	342 – 1223m	400 – 1005m
	Siwalik Main Unconformity			
Gondwana Group	Upper Gondwana	1065–1130m 2078m	1223–1701m 1633m	1005–2078m 2190m
	Lower Gondwana	1130–3143m	1701–2844m	2078–3299m

PREVIOUS WORK

Venkatachala and Rawat (1979) first carried out the palynological studies on PRN-A well with record Early Triassic palynoflora and suggested the presence of Early Triassic sediments between 1700-1900m depth-interval. Mehrotra and Thakur (1990) studied the KRD-A well and recorded Permian palynological assemblages corresponding to Barakar, Raniganj and Panchet formations palynofloras. Since then, no serious attempt was made to study the complete Gondwana sediments of this basin. Later on, Prasad and Pundeer (1998) carried out detailed palynological studies on the Gondwana sediments of Purnea Basin in KRD-A (1065-3143m), PRN-A (1211–2844m) and LHL-A (1110–3300m) wells. They (op.cit.) recognised 13 palynological zones in the Gondwana succession, and precisely dated the different sedimentary units based on the recovered palynological assemblages.

MATERIAL AND METHODS

In the present work, detailed palynological studies have been carried out on the Gondwana sediments encountered in KRD-A (1065-3143m), PRN-A (1223–2844m) and LHL-A (1005–33299m) wells to determine precise age and depositional environment of different Gondwana lithounits. Comparison of recognized palynological are attempted with those known from adjoining Rajmahal and Bengal basins. Additionally, presence of unconformities within Gondwana succession of Purnea Basin are also identified to provide the sequence stratigraphic framework for this basin.

OBSERVATION AND INTERPRETATION

Identification of palynological zones and inferred age

In all the above three studied wells of Purnea Basin, thirteen (13) distinct palynological zones are recognized in the Gondwana sediments (Table-2). The recognized palynological zones are closely comparable with the standard Gondwana palynological zones established in different Gondwana basins of India by Tiwari and Tripathi (1992), Prasad *et al.* (1995) and Prasad (1997), hence assigned to those zones. In addition, two palynological zones are also identified in Siwalik sediments.These zones are summarized in Table 2. Recognised palynological zones and their distribution in PRN-A, KRD-A and LHL-A and identified sequences are shown in Fig. 2.

Identification of unconformities and their span

The Gondwana succession in Purnea basin is bounded by two major unconformities of first order magnitude. The lower one is the Proterozoic-Lower Paleozoic unconformity which separates the Gondwana from the underlying Paleoproterozoic Mungher Phyllites/Schists or Chhota Nagpur Granitic Complex. The span of hiatus is approximately 2200My from ca 2500Ma to 299Ma. The younger unconformity is present between the Gondwana and the overlying Siwalik successions, and is about 187My duration from ca 203Ma to 16Ma (Fig.2). Thus, Gondwana succession in Purnea Basin represents a First Order Permo-Triassic sequence.
Addionally, four second order unconformities/hiatuses are also recognized within the Gondwana succession in Purnea Basin. These are briefly mentioned below:

i). late Early Permian (Late Sakmarian) Hiatus

This hiatus is recognized between the *Parasaccites korbaensis* Zone and *Crucipollenites monoletes* Zone in all the studied wells. This hiatus is present between the Karandighi and Salmari formations and involves the absence of upper part of Talchir or its equivalent sediments in Purnea Basin corresponding to *Divarisaccus lelelie-Didecitriletes bellus* Zone, and spans about 6My from ca 290Ma to ca 284Ma (Fig. 2).

ii). Middle Permian Hiatus

This hiatus is recognized in between the *Faunipollenites varius* Zone of Early Permian (Kungurian) and *Gondisporites raniganjensis* Zone of early Late Permian (Wuchiapingian) in all the studied wells. The *Densipollenites indicus* Zone of Roadian age that broadly corresponds to the Barren Measures, is absent in this basin. Sediments of Katihar Formation (Barakar equivalent) are overlain by the sediments of Dinajpur Formation (Raniganj equivalent), showing the non-deposition of Barren Measures equivalent sediments. The duration of hiatus is ca 11My from ca 276Ma to 265Ma (Fig. 2).

iii). Permo-Triassic boundary Hiatus

This hiatus is recognized in between the *Densipollenites magnicorpus* Zone of Late Permian (Changsingian) and *Lunatisporites pellucidus* Zone of basal Early Triassic in all the studied wells. The duration of hiatus is ca 3My from ca 254Ma to 251Ma (Fig. 2). Moreover, a major megafloral change have been observed across the Permo-Triassic boundary in all the Indian Gondwana basins with disappearance of *Glossopteris* Flora and appearance of *Dicroidium* Flora (Lele, 1964).

iv). upper EarlyTriassic Hiatus:

This hiatus is recognized between the *Limatulasporites fossulatus-Aratrisporites parvispinosus* Zone of early Middle Triassic (Anisian) and *Dubrajisporites isolatus-Staurosaccites quadrifidus* Zone of Middle Triassic (Ladinian). This hiatus involves the absence of *Rajmahalispora rugulata* Zone and *Brachysaccus ovalis* Zone of lower Middle Triassic (Late Anisian). Lithologically, this unconformity separates the lower parts of Lahil Formation with upper one. The span of hiatus is ca 5My from 245Ma to 240Ma.

Table-2: Recognised palynological assemblage zones in Gondwana and Siwalik sediments in drilled wells of Purnea Basin, with inferred age

Zn. No.	Assemblage Zones	Age
CSPZ. II	*Podocarpus imbricatus* Zn.	Late Pliocene
CSPZ. I	*Magnastriatites howardii* Zn.	Late Miocene - Early Pliocene
---------- **Siwalik Main Unconformity** ----------		
GPZ. XIII	*Rimaesporites potoniei-Samaropollenitespeciosus* Zn.	Late Ladinian-Carnian (Middle to Late Triassic)
GPZ. XII	*Dubrajisporites isilatus- Staurosaccites quadrifidus* Zn.	Ladinian (Middle Triassic)
GPZ. XI	*Limatulasporites fossulatus– Aratrisporites parvispinosus* Zn.	Olenkian-Anisian (Early to early Middle Triassic)
GPZ. X	*Lundbladispora brevicula-Krauselisporites saeptatus* Zn.	Olenkian (Early Triassic)
GPZ. IX	*Lunatisporites pellucidus-Klausipollenites schaubergerii* Zn.	Induan (Early Triassic)
GPZ. VIII	*Densipollenites magnicorpus* Zn.	Changsingian (Latest Permian)
GPZ. VII	*Gondisporites raniganjensis* Zn.	Wuchiapingian (Late Permian)
GPZ. VI	*Faunipollenites varius* Zn.	Late Artinskian -Kungurian (Early Permian)
GPZ. V	*Scheuringipollenites barakarensis* Zn.	Early Artinskian (Early Permian)
GPZ. IV	*Crucisaccites monoletus* Zn.	Early Artinskian (Early Permian)
GPZ. III	*Parasaccites korbaensis* Zn.	Middle Sakmarian (Early Permian)
GPZ. II	*Rugassacites orbicularis- Didecitriletes bellus* Zn.	Early Sakmarian (Early Permian)
GPZ. I	*Plicatipollenites gondwanensis* Zn.	Asselian-Tastubian (Early Permian)

The thick succession of Neogene (Siwalik) sediments rests over the Late Triassic Gondwana sediments in this basin, indicating the absence of latest Triassic, entire Jurassic, Cretaceous and Paleogene sediments. It indicates the presence of a major hiatus of about 187My duration approximately from 203Ma to 16Ma (Fig.2).

Thus, the total Gondwana sequence in Purnea Basin is subdivided into 5 IInd order sequences from older to younger, mentioned here as GND.IISQ-1A, GND.IISQ-1B, GND.IISQ-1C, GND.IISQ-1D and GND.IISQ-1E (Fig.2).

Identification of sequences:

Based on the recognition of a major unconformity (ca 187My) in between the Gondwana and Siwalik successions, the complete Gondwana succession (Permo-Triassic) is grouped under a Irst order sequence, referred to as the **GND**. **ISQ-1**. This sequence is further subdivided into five IInd order sequences, viz. GND. IISQ-1A, GND.IISQ-1B, GND. IISQ-1C, GND.IISQ-1D and GND.IISQ-1E (Fig.2). The oldest second order sequence (IISQ-1A) represents the fluvio-marine Early Permian Karandighi (Talchir) sediments in Purnea Basin. The succeeding IISQ-1B sequence includes the thick sandstone, coal and carbonaceous shale unit of Salmari and Katihar formations, and correlatable with the Karharbari-Barakar sedimentation cycle of late Early Permian in Indian Gondwana. The third second order sequence (IISQ-1C) is represented by the sediments of Dinajpur Formation and comparable with the Raniganj (Late Permian) sedimentation cycle (Fig.2). Its top is marked by the Permo-Triassic boundary unconformity.

The fourth second order sequence (IISQ-1D) includes the thick khaki to maroon-coloured sandstone and siltstone, and represents the lower parts of Lahil Formation in Purnea basin (Fig.2). Its lithology and palynofloras are comparable with the Early Triassic Panchet Formation of Bengal and Damodar basins. The uppermost second order Gondwana sequence in Purnea Basin (IISQ-1E) is represented by upper parts of Lahil Formation of Ladinian-Carnian (Middle to Late Triassic) age and its palynofloras are comparable with those recorded from the Dubrajpur Formation in adjoining Rajmahal Basin and Durgapur Formation in Bengal and Damodar basins (Fig.2).

The Gondwana succession in the Purnea Basin is overlain by the Neogene Siwalik sediments, which are grouped here as the **SWK. ISQ-2**. Further subdivision of this sequence is not possible biostratigraphically due to its poorly fossiliferous nature. However, on the basis of seismic parameters, this sequence has been further subdivided into 3 IInd order sequences, viz. SWK. IISQ-2A, SWK.IISQ-2B and SWK. IISQ-2C (Fig.2).

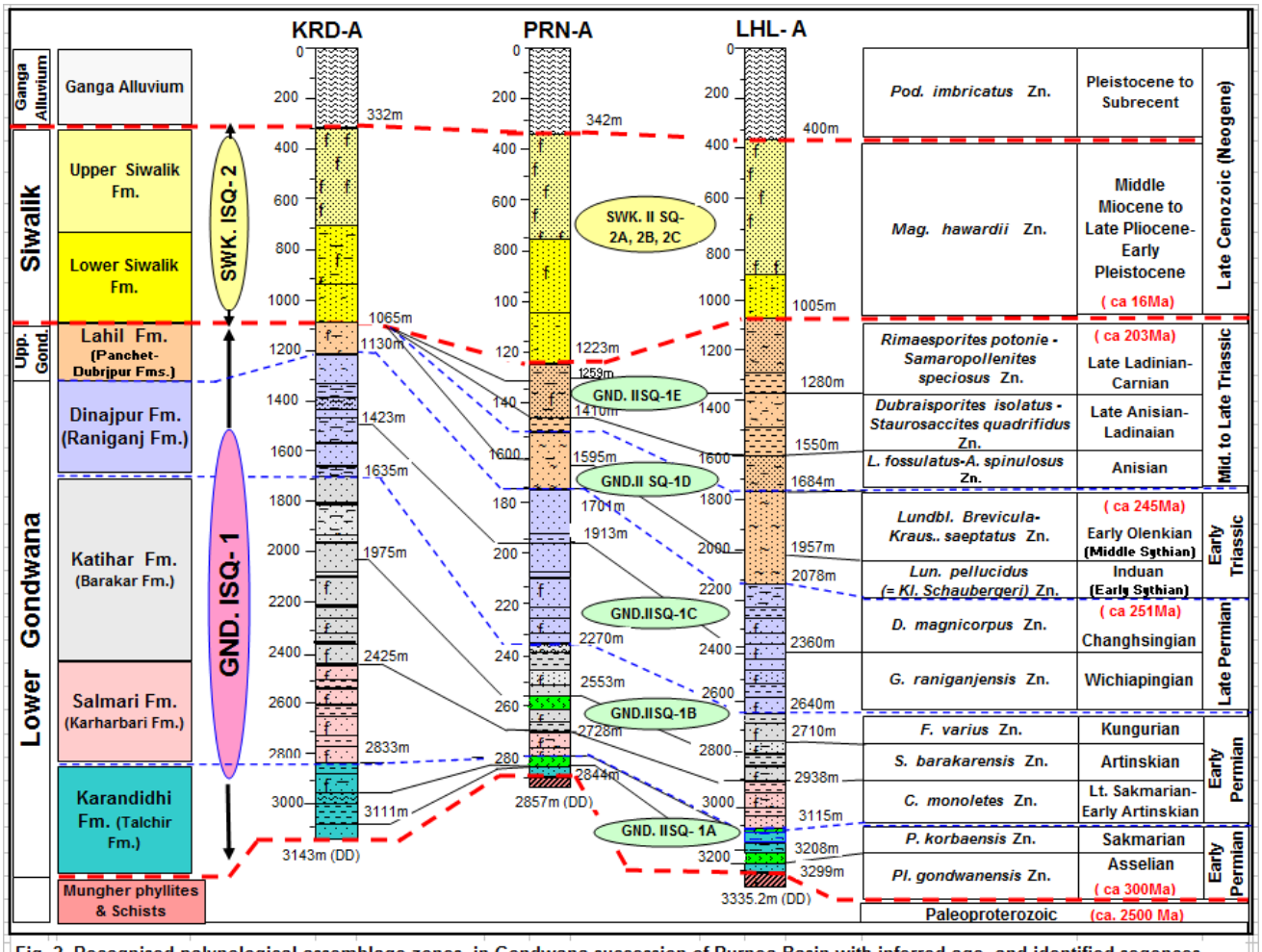

Fig. 2. Recognised palynological assemblage zones in Gondwana succession of Purnea Basin with inferred age, and identified seqences

DISCUSSION

The present biostratigraphic and geological studies on the Gondwana sediments in key wells of KRD-A (1065-3143m), PRN-A (1223–2844m) and LHL-A (1005–3299m) establish the occurrence of a thick Lower (Permian) as well as Upper Gondwana (Triassic) sediments in the Purnea Basin. Most important observation is the absence of Rajmahal traps and intertrapeans which are well-developed in the adjoining Rajmahal, Galsi, Panagarh and Bengal basins that envelop the Gondwana sediments in these basins. Rajmahal traps and

intertrapean beds are also reported in the subsurface in number of wells drilled in western parts of Bangladesh in Singra, Kuchma, Bogra and Jamalganj areas (Fig.1) above the Gondwana succession, and its occurrence in the Purnea Basin can not be ruled out. Prasad and Phor (2009), while reviewing the Gondwana stratigraphy of India, have excluded the Rajmahal traps and associated sediments from the Gondwana cycle. They (op. cit.) opined that the Rajmahal volcanic event was associated with the break-up of Indian Plate from East Gondwanaland and subsequent opening of the Bay of Bengal during Late Jurassic (Tithonian) time. Additionally, the above volcanic event took place about 65-70My later after the termination of Gondwana sedimentation during Late Triassic. The associated sediments of Rajmahal volcanics recorded marine dinocysts of Early Cretaceous (Neocomian) aspect in Rajmahal, Bengal and Mahanadi basins (Prasad and Pundir, 2012) and indeed represent post-Gondwana Late Jurassic-Early Cretaceous (Tithonian-Neocomian) early synrift sediments in these basins. Prasad and Phor (2009) have argued that the characteristic Gondwana in India are represented by the Permo-Triassic sediments only which occur below the major Jurassic unconformity of ca 65-70My (Hetenginian to Kimmeridgian) in all the Indian Gondwana basins.

The thirteen palynological zones identified in Gondwanas of Purnea Basin closely compare with the palynological zones established in different Indian Gondwana basins. The Lower Gondwana palynofloras of Purnea Basin show closed resemblance with the characteristic palynological assemblages of Talchir, Karharbari, Barakar and Raniganj formations and provide strong palynological evidences for the presence of above Lower Gondwana lithounits or their equivalent and named in this basin as Karandighi, Salmari, Katihar and Dinajpur formations respectively. The Upper Gondwana (Triassic) Palynofloras are represented by Early, Middle and Late Triassic palynological assemblages corresponding to the Panchet and Supra–Panchet (Durgapur/Dubrajpur formations), and collectively named here as the Lahil Formation. However, as an unconformity is recognized within the lower parts of Lahil Formation. Thus, this unit should be subdivided into two members, viz. Lower Lahil Formation and Upper lahil Formation corresponding to Panchet (Early Triassic) and Dubrajpur formations respectively. The palynological assemblages corresponding to the Rajmahal palynofloras of Late Jurassic-Early Cretaceous (Tithonian-Neocomian) are not recorded and represented by non-depositional hiatus of Jurassic and Early Cretaceous. In addition, absence of characteristic Late Cretaceous and Early Tertiary (Palaeogene) palynofloras in the studied wells sections further suggest a major hiatus between the Permo-Triassic Gondwana and Neogene Siwalik sediments with the absence of Jurassic, Cretaceous and Cenozoic sediments upto Early Miocene in the Purnea Basin. However, in the case of Rajmahal, Bengal and Mahanadi basins, the post-Gondwana hiatuses are of less duration due to occurrence of Rajmahal Traps and intertrappeans or their equivalent sediments above the Gondwana sediments.

The source-rock and subsidence history data suggest that the Lower Gondwana sediments are with rich TOM and TAI of 2.75+, and were within gaseous window from Middle Triassic to Late Cretaceous. It might have charged the overlying Triassic arenaceous sediments of Lahil Formation. The Upper (Triassic) Gondwana are with the TAI of 3.0-3.0+, but have poor TOM which are inadequate to generate hydrocarbon.

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