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ABSTRACTS

"Linkage of Cretaceous solid earth dynamics, greenhouse climate, and response of ecosystems on land and in the oceans in Asia"

Cretaceous Earth Dynamics and Climate in Asia

CONTENTS

Late Cretaceous-Early Palaeocene Deccan volcanism and its impact on floral diversity on the Indian subcontinent: A new insight

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Deccan Continental Flood Basalt Province covering an area of about 500,000 km^2 with an eruptive volume of $13x10^6$ km^3 (Jay and Widdowson 2008) is one of the largest flood basalt eruptions in the Earth's history. Duration of Deccan volcanism is believed to be 6-7 my (Pande et al., 2017) with voluminous emplacement post Cretaceous-Paleogene (K-Pg) boundary (Sprain et al., 2019). The Deccan volcanic associated sediments 'infratrappean' (deposited before the arrival of flows) and 'intertrappean' sediments (deposited in between the two volcanic flows) were deposited in different sub-provinces. The flows and intertrappean sediments (Maastrichtian-Palaeocene) are time transgressive, having their own deposition history (Hansen et al 2005).

Study of palynoflora along with volcanostratigraphy and paleomagnetic polarity analysis in different sub-provinces shows that first floral change in the Deccan volcanic province (DVP) started with the onset of Deccan volcanic activity. Initial volcanic activity was conducive for the growth of plants as palynoflora shows distinct diversity in the intertrappean deposited in Maastrichtian Chron 30N in Malwa Group and Mandla Group. The presence of charcoal at various stratigraphic levels (Thakre et al., 2017; Mohabey et al., 2018) also indicates good vegetation. This vegetation pattern continued in Maastrichtian Chron 29R. The Maastrichtian (Chron 30N and 29R) intertrappeans are characterised by dominance of taxa such as *Azolla cretacea*, *Gabonisporis vigourouxii*, *Crybelosporites intertrappea*, *Aquilapollenites bengalensis*, *Jiangsupollis* spp., *Farabeipollis* spp., These palynomorphs are present in various concentration in almost all the intertrappean beds. The Maastrichtian pteridophyte-angiosperm rich intertrappean floral assemblage is distinctly different from gymnosperm-angiosperm rich palynoflora of infratrappean possibly, due to change in climate at local levels.

Recently carried out studies with a new chronostratigraphic constrained data from intertrappean sediments from south-eastern part of Deccan volcanic province shows second floral change started in latest Maastrichtian before K-Pg boundary. This flora is characterised by disappearance of most of the marker Maastrichtian taxa, presence of Maastrichtian-Palaeocene taxa (*Gabonisporis vigourouxii*, *Mulleripollis bolpurensis*), appearance of Palaeocene taxa (*Striacolporites striatus*, *Echistephanocolpites meghalayaensis*, *Palmaepollenites neyvelii*, *Aesculipollis)* and distinct increase in diversity of grasses. Potential driver of such change is increase in volcanic activity close to the K-Pg boundary and the associated environmental changes (Renne et al., 2015). Importantly, in contrast to the numerous Maastrichtian palynomorph-bearing intertrappean beds in the DVP, only three intertrappean localities are interpreted as Palaeocene: Ninama (Samant et al., 2014), Lalitpur, (Singh and Kar, 2002), and Surli, (Thakre et al., 2016). Majority of palynotaxa from these intertrappean are unique and only a few palynotaxa are common which suggest that in comparison to the Palaeocene flora, the Maastrichtian flora was more stable.

The palynofloral changes observed on the terrestrial sequence of Deccan volcanic province are in contrast to the changes observed in Western Interior of North America where the major extinction event of Cretaceous “K taxa” occurs at the KPB and earliest Palaeocene was marked by the fern spike (Nichols and Johnson, 2008; Bercovici et al., 2009).

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Palynological analysis from the Palaeo Kathmandu Lake sediment exposed at the northern and southern part of the Kathmandu valley and their climatic implications

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The Kathmandu basin sediment holds huge information of the climate and ecological changes from the Pliocene-Pleistocene-Holocene time period. The basin encloses numerous vertebrate and plant fossils that can be used as proxies to reconstruct and investigate the past environment. The present work features the palynological analysis of sediment samples obtained from the Lukundol Formation exposed in Pharsidol area southern part of the Kathmandu valley and the Dharmasthali Formation equivalent to (Lukundol Formation) exposed in the northern part of the Kathmandu valley. The pollen assemblages zones were divided according to pollen percentage diagram based on CONISS cluster analysis. The pollen assemblages resembles angiosperm pollen were dominant over gymnosperm pollen in both the sections. The main pollen percentages include higher percentage of *Pinus, Quercus, Tsuga, Alnus, Betula*, Compositae, Poaceae species in both northern and southern section of the palaeo Kathmandu Lake sediments. The coexistence approach analysis applied in the palynomorphs revealed slightly warmer climate in the present than in the Plio-Pleistocene time period. The non-arboreal pollen (NAP) shows higher frequency than arboreal pollen (AP) in different pollen zones suggesting forest floor rich in various herb and shrub vegetation during the deposition time period of the respective sections.

Key words Palaeo Kathmandu Lake, Co-existence approach, pollen assemblages, past environment, Climate.

The Early Cretaceous coal-forming plants of the Southern Russian Far East and North-East China

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We have studied the Lower Cretaceous coal-bearing deposits of the Lake Gusinoe, Tugnui, Tarbagatai, Bada, Chita-Ingoda, Chikoi, Bukachacha, Turga-Kharanor basins of Transbaikalia, Bureya Basin of the Amur River Region, the Razdolnaya and Partizansk basins of the Primorye Region. Also, rich paleobotanical material was obtained from the Lower Cretaceous coals of the Dongning, Huolinhe, and Fuxin coal mines in North East China. The coal samples were processed according to the standard methods. After chemical maceration, dispersed cuticles of fossil plants composing coal were obtained, their taxonomic affinity was determined, and coal-forming plants were identified. Palynological analysis of both clastic layers and coals allowed us possible to reveal the vegetation of the basin in which the formation of swamp plant communities took place. The coal-forming plants of the Selenga and Kholboldjin formations in the Lake Gusinoe Basin, the Tugnui Formation in the Tugnui Basin, the Kuti Formation in the Tarbagatai and Chikoi basins are ferns, Umaltolepidaceae, and pinaceous conifers. In the Kuti Formation in the Bada Basin they are represented by miroviaceous conifers *Arctopitys* sp. A and cheirolepidiaceous conifer *Tarphyderma* sp. nov. The following plants were found in coals of the Kuti Formation of the Chita-Ingoda Basin: Bennettitales sp. indet., *Czekanowskia vachrameevii* Kiritchkova et Samylina, *Phoenicopsis parva* Vassilevskaja, *Ph.* sp., *Sphenobaiera* sp., *Ginkgo manchurica* (Yabe et Oishi) Meng et Chen, *G.* sp., *Pseudotorellia palustris* Shi, Herrera, Herendeen, Leslie, Ichinnorov, Takahashi et Crane, *Ps. resinosa* Shi, Herrera, Herendeen, Leslie, Ichinnorov, Takahashi et Crane, *Pseudotorellia* sp., *Elatides* cf. *zhoui* Shi, Leslie, Herendeen, Ichinnorov, Takahashi, Knopf et Crane, *Pagiophyllum* sp. It was found in the coals of the Turga Formation in the Bukachacha Basin *Pseudotorellia transbaikalica* Bugdaeva, *P.* sp., *Elatides asiatica* (Yokoyama) Krassilov, *Pityophyllum* sp. 1, *Pagiophyllum* sp., P. (*Farndalea fragilis* Bose) sp. The main coal-forming plants of the Kuti Formation in the Turga-Kharanor Basin are *Nilssoniopteris* aff. *prynadae* Samylina, *Pseudotorellia kharanorica* Bugdaeva, *Elatides* sp. A, *E.* cf. *zhoui*, *Holkopitys* sp. A, *Pagiophyllum* sp. In the Bureya Basin during the sedimentation of Chagdamyn Formation *Pseudotorellia* sp. and *Podozamites doludenkoae* Nosova mainly supplied material for the formation of coal deposits. In the younger Chemchukin Formation they are replaced by *Pseudotorellia* cf. *palustris* and *Elatides asiatica*. The coal-forming plants of the Lipovtsy Formation, Razdolnaya Basin, Primorye Region, are dominated by ferns, bennettites, and conifers Miroviaceae, Taxodiaceae, and Cheirolepidiaceae (Bugdaeva, Markevich, 2009). The simultaneous coals (Starosuchan Formation) of the Partizansk Basin, formed in coastal marine conditions, are composed mainly of the remains of gleicheniaceous ferns and *Elatides asiatica*. The Miroviaceae, Umaltolepidaceae, and bennettites are subordinate (Bugdaeva et al., 2014). The Early Cretaceous flora of the Fuxin Basin (Liaoning Province, China) was dominated by *Elatides asiatica* (Chen et al., 1981), however, its remains were not found in the coals. In all likelihood, these conifers in more southerly localities grew up on uplands and were nor part of the lowland swamp plant communities, which were dominated by *Marskea* sp. (Taxaceae). The

Dongning coal mine (Heilongjiang Province, China) is located in the Chinese part of the western part of the Razdolnaya Basin. Their coals were formed by the remains of the Miroviaceae and Taxodiaceae (*Athrotaxites orientalis* Deng et Chen), as well as bennettites and gleicheniaceous ferns. The coals of the Huolinhe Basin (Inner Mongolia Province, China) are composed of the abundant remains of diverse bennettites, ginkgoaleans, Umaltolepidaceae, and conifers. The fossil flora of the coal seams of the Russian Far East and North-East China included a number of common taxa that can be used for stratigraphical correlation of the Lower Cretaceous deposits of this region. On such a vast area in the Early Cretaceous, swamps were widely distributed. The vegetation of lowland was composed of representatives of ferns, bennettites, and conifers. It was different from that growing in uplands.

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Nesting pattern and taphonomic conditions of the titanosaur nesting sites from the Upper Cretaceous Lameta Formation of the lower Narmada valley, India

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The titanosaur nests from the Indian subcontinent are well-known for their wide geographic distribution, extending from Jabalpur (Madhya Pradesh (M.P.)) in the east to Rahioli (Gujarat) in the west along the Narmada River valley along with a few isolated occurrences in Betul district (central India), Nand-Dongargoan basin (south-central India), and Cauvery basin (in southern India). While the titanosaur nests from the upper Narmada valley have been previously studied to understand several aspects of dinosaur nesting sites (Sahni et al., 1994; Tandon et al., 1995), the same has not been done for the nests of lower Narmada valley. Here we present an account of widely distributed titanosaur nests from the Bagh-Kukshi areas of Dhar district, M.P. and a general view of their taphonomic and palaeoenvironmental aspects.

The titanosaur nests from Jabalpur and Balasinor are preserved in the Lower Limestone unit of the Lameta Formation. However in Bagh-Kukshi areas in M.P., the complete stratigraphic section of the Lameta Formation is not preserved. On comparison to those of Jabalpur, the nests from these areas documented from the sandy limestone and calcareous sandstone outcrops are considered to be derived from possible lateral equivalent of the Lower Limestone unit. These dinosaur eggshells exhibit spherulitic basic type, discretispherulitic/tubospherulitic morphotype with compactituberculate surface ornamentation which suggest that they belong to the titanosaur sauropod dinosaur taxa. These nests, isolated eggs, and eggshell fragments are identified to represent six oospecies, namely *Megaloolithus cylindricus*, *M. jabalpurensis*, *M. dhoridungriensis*, *Fusioolithus mohabeyi*, *F. baghensis*, and *F. padiyalensis* based on microstructure and ultrastructure. This points towards a high diversity in the oospecies of the Bagh-Kukshi sites.

While the nests in upper Narmada valley show around eight eggs grouped in clutches, those in lower Narmada valley have eggs as many as twenty in number. Several other oological features are commonly present in the these titanosaur nests such as hatching window and pathological eggs, with an additional discovery of a pathological ovum-in-ovo egg reported from the Bagh-Kukshi areas of Dhar district. The common nesting pattern is circular type, however, a linear nesting arrangement is also observed. Reproductive behavior and features, such as, colonial nesting, lack of parental care, and presence of resorption craters are observed in these nests. Based on mapping of the nesting sites in Bara Simla Hill, Jabalpur, it was suggested that nesting took place at higher geomorphic surfaces while the bones accumulated in a lake, such as in a palustrine flat system (Sahni et al., 1994). In lower Narmada valley, sedimentary structures, such as, autobrecciation, grainy intraclasts, spar rims, quartz veins, chert bands and nodules, mottling, calcitic nodules, alveolar-septal fabric, and shrinkage cracks indicate palustrine depositional setting in a low-gradient, low energy setting close to the margins of ponds occurring in association with fluvial/alluvial plain, the latter of which is indicated by presence of maroon-colored sandstone. The presence of similar oospecies in India, Argentina, France, and Morocco indicates close palaeobiogeographic connections between India, Southern Europe, South America and Africa. A comprehensive analysis of these nests has opened up several observations and avenues for future research.

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Deccan Traps volcanism caused the extinction of non-avian dinosaur in SE China

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The debate concerning the relative importance of the Chicxulub bolide impact and/or Deccan Traps (DT) volcanism as the cause of the extinction of non-avian dinosaurs during the end of the Cretaceous has lasted for several decades. Here, mercury (Hg) and its isotopic composition, heavy metals, and high-resolution magnetic parameter measurements were undertaken at a continental sedimentary basin (Nanxiong Basin, SE China). The results show that Hg exhibited anomalies from 66.4 to 65.6 Ma, with near-zero to positive Δ^{199}Hg values, which reflected the eruption of Deccan Traps (DT) volcanism. Besides, Hg and other heavy metal anomalies coincided with the gradual extinction of non-avian dinosaurs and the delayed expansion of large mammals, indicating that DT volcanism played a key role in the mass extinction and the subsequent recovery. Two transient warming events (the Late Maastrichtian warming event (LMWE) and Dan-C2) were identified by magnetic susceptibility and stable isotopes. Time-series analyses demonstrated that these warming events occurred at the maxima of 405-kyr long eccentricity cycle, moreover, they were of a comparable size in the magnitude of warming, suggesting that LMWE was not the primary trigger for the extinction, though it may aggravated the complicated situation.

Titanosaurs from India and Pakistan; Cretaceous archosaurs from Pakistan

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Indian titanosaur taxa from Lameta Formation are informal and un-official (except *Isisaurus*) while Pakistani titanosaur taxa from the Latest Maastrichtian (67-66 Ma) Vitakri Formation are formal and official by the rules of the ICZN (Malkani 2021a,b). From India Lydekker established *Titanosaurus indicus* and *Titanosaurus blanfordi* on two caudal vertebrae (each); Huene and Matley established *Antarctosaurus septentrionalis* on braincase and postcranial bones, and further referred bones to *Titanosaurus indicus, Titanosaurus blanfordi* and *Laplatasaurus madagascariensis*; Mathur and Srivastava established *Titanosaurus rahioliensis* on teeth (apparently one tooth); Hunt and others suggested *Jainosaurus* name for *Antarctosaurus*; Jain and Bandyopadhyay established *Titanosaurus colberti* (*Isisaurus colberti*) on associated postcranial skeleton. Recently Malkani extended the three titanosaur taxa (*Gspsaurus, Saraikimasoom* and *Pakisaurus*) from Pakistan to India and one taxon (*Isisaurus*) from India to Pakistan. From Pakistan Malkani established *Gspsaurus, Maojandino, Marisaurus, Saraikimasoom, Nicksaurus, Balochisaurus, Pakisaurus, Sulaimanisaurus* and *Khetranisaurus*. Before August 2021 all of these Pakistani titanosaurs were informal. Among these *Gspsaurus, Saraikimasoom Pakisaurus, Sulaimanisaurus* and *Khetranisaurus* were formally published in August 5, 2021 (Malkani 2021b) and other four titanosaurs like *Balochisaurus, Nicksaurus Marisaurus* and *Maojandino* were formally described in September 26, 2021 (Malkani 2021a). Pakistani titanosaur recently found materials are considerably more than the Indian titanosaur materials reported since about 2 centuries. Titanosaur snouts and some guide fossils from Pakistan have no parallel in India. Some Pakistani titanosaurs based on associated cranial and postcranial skeletons and some based on vertebral and appendicular associated assemblages, while Indian titanosaurs based on only a few bones except *Isisaurus colberti*. Pakistani titanosaur taxa show overlapping holotypic bones which provide the best opportunity for correlation and comparison with each other and also Indian and global world coeval titanosaurs. Recently Malkani made comparison of Indian and Pakistani titanosaurs (Malkani 2021a). The *Gspsaurus, Saraikimasoom* and *Pakisaurus* have cranial and associated postcranial materials with numerous distinguishing features.

Gspsaurus characterized by V-shaped lower teeth row while *Saraikimasoom* has U-shaped lower teeth row; conical slender teeth gradually decreasing width toward tip (except tip); teeth contact with each other is slightly spaced; relatively less reduction of ventral width of caudals; scapular short articular surface for coracoid (Figure 1) while *Isisaurus* scapula has long articular surface; humerus with anteriorly expanded radial condyle while *Sulaimanisaurus* has no expanded radial condyle (Figure 1); proximal tibia is biconvex lense shaped with anteroposteriorly more width than transverse width while *Pakisaurus* and *Sulaimanisaurus* have flattened tibia (transversely not expanded) and *Balochisaurus* has tilted subsquare/rectangle shaped proximal tibia with equal transverse and anteroposterior width; transversely elongated oval or parallelogram shaped distal tibia while *Pakisaurus* and *Sulaimanisaurus* have anteroposteriorly broad distal tibia (Figure 1). ***Saraikimasoom*** characterized by U-shaped lower teeth row while *Gspsaurus* has V-shaped lower teeth row (Figure 1); conical slender teeth gradually decreasing width toward tip (except tip); teeth closely contact with each other while *Gspsaurus* has spaced teeth (not closely contacted with each other especially mid of teeth row). *Saraikimasoom* snout has fracture on anterodorsal part providing clue of subterminal nare of titanosaur or crocodile, it will be confirmed by internal scanning.

Marisaurus characterized as slight ventral reduction of caudals like *Gspsaurus* while *Balochisaurus* and *Nicksaurus* have strong reduction of caudals, and *Pakisaurus, Sulaimanisaurus and Khetranisaurus* have mostly no ventral reduction of caudals; ball like biconvex first caudal while *Balochisaurus* has broad first biconvex caudal; pubis iliac symphysial part is low and reduced, while the *Isisaurus* has elevated iliac symphysial; close occurrence of low iliac symphysial and adjoining wide and thick glenoid (Figure 1). ***Sulaimanisaurus*** characterized by squarish shaped caudals with no strong ventral reduction, no expanding radial condyle and flattened tibia (Figure 1). ***Khetranisaurus*** is unique among Indo-Pakistani titanosaurs having ventral width more than dorsal width of caudals. ***Pakisaurus*** has tall caudals with no or slight ventral reduction; scapular short articular surface for coracoid; humeral expanded radial condyle and flat proximal tibia (Figure 1). ***Nicksaurus*** characterized by conical slender teeth gradually decreasing width toward tip (except tip), closely contacted teeth with each other like *Saraikimasoom*, while *Gspsaurus* has spaced teeth (not closely contacted with each other especially mid of teeth row); strong ventral reduction of mid caudals; anteroposteriorly compressed chevron; and transversely long oval shaped distal tibia (Figure 1). ***Balochisaurus*** characterized by first biconvex caudal (Figure 1); strong ventral reduction of width and length of mid caudals; anteriorly expansion of radial condyle of distal humerus; stockiest tilted subsquare or subrectangle shaped proximal tibia with equal transverse and anteroposterior width (Figure 1).

Two theropods like *Vitakridrinda* and *Vitakrisaurus* are known from Pakistan. *Vitakridrinda* holotypic fossils according to original formal publication (Malkani 2021b) as per ICZN rules are more than 10 teeth, a pair of femora and a pair of dorsal vertebrae, and referred dorsal and caudal vertebrae and a few metapodials. *Vitakridrinda* has short and broad oval teeth (like *Indosuchus raptorius),* subcircular teeth (while *Vitakrisaurus* and *Indosuchus* have oval shaped teeth convexing lingually and labially), teardrop type teeth (like *Rahiolisaurus*); proximal femoral shaft with slightly transversely broad with thick peripheral bone enveloped on the central hollow cavity while distal shaft is more broader; its femoral anterior trochanter is vertically oriented and blunted at tip; its ventrally broad centra (without ventral keel) having ventral smooth plain and forming reduced neck at the dorsal portion which also differentiates it from the *Rajasaurus* and *Rahiolisaurus* both have dominant ventral keel on dorsal centra. *Vitakrisaurus* holotypic fossils according to original formal publication (Malkani 2021b) as per ICZN rules are a manus, ulna, caudal vertebrae and a few limb bones, and referred anterior dentary symphysis, dentary ramus with articulated teeth, dorsal vertebra and a few limb bones from Pakistan and an amphicoelous vertebra with small sized chevron from India. *Vitakrisaurus* has weak anterior articulation of thick and deep dentary rami with external pitted and lineated structures; V-shaped anteriormost end of dentary symphysis (blunted as w-shaped) while *Rahiolisaurus* anterior jaw ramus shows curvature representing U-shaped anterior symphysis.

Five mesoeucrocodiles are known from Pakistan. *Pabwehshi* and *Induszalim* have deep rostrum but terminal and subterminal nares respectively. *Sulaimanisuchus* have enlarged fourth dentary tooth which is differentiated from small fourth dentary tooth of *Pabwehshi*. *Mithasaraikistan* has transversely wide snout while *Pabwehshi* and *Induszalim* have deep snout. Teeth size and orientation differentiate these from others. *Khuzdarcroco* was based on a partial slender rib.

Snake *Wadanaang* with slender and straight teeth only recurved on tip differed from the stocky and low angle arc shaped teeth of *Sanajeh*. *Wadanaang* precloacal vertebra has ventral keel and relatively broader neural canal. Pterosaur *Saraikisaurus* based on slender and pneumatic lower beak with partially overlapped oval teeth. *Wasaibpanchi* is the first Cretaceous bird in Indo-Pakistan subcontinent which has asymmetric heterodont trigonal and triconvex relatively less transversely compressed teeth (with broad base and asymmetric anterior and distal ends) while *Archaeopteryx*, *Hesperornis* and *Ichthyornis* have flattened and transversely more compressed teeth. *Wasaibpanchi* bore long conical teeth while Pengornis bore short blunted teeth to eat arthropods. *Wasaibpanchi* bore relatively less transversely compressed large teeth while bohaiornithids enantiornitheans bore strongly transversely compressed large, robust and somewhat conical teeth. *Wasaibpanchi* bore long teeth while *Gobipteryx* has no teeth. *Wasaibpanchi* has larger teeth cavity which is enveloped by blue thin enamel layer and then outer thin white enamel layer, while *Archaeopteryx* has flattened enamel crown set upon a wider semi elliptical bony base, and theropods and mesoeucrocodiles from Pakistan have relatively thick enamel on short core cavity. The *Wadanaang* snake and *Wasaibpanchi* bird were preying on the egg (possibly egg nesting) of *Gspsaurus* titanosaurian sauropod (Malkani 2021a,b).

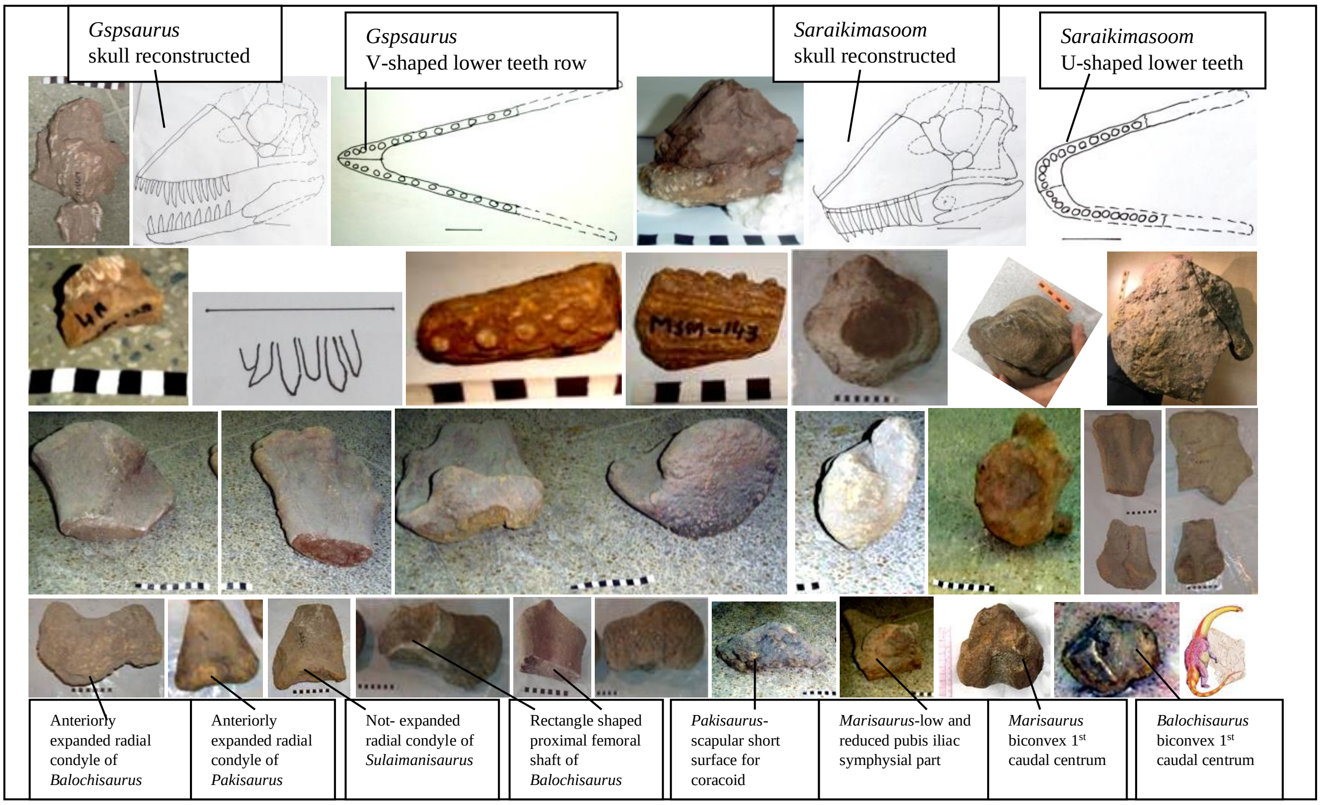

Figure 1. **Row 1**, photo/p1, *Gspsaurus* skull; p2, *Gspsaurus* skull reconstructed; p3, *Gspsaurus* V-shaped lower teeth row; p4, *Saraikimasoom* skull; p5, *Saraikimasoom* skull reconstructed; p6, *Saraikimasoom* U-shaped lower teeth row. **Row 2**, p1,2, *Nicksaurus* closely contacted articulated teeth; p3,4, *Pakisaurus* widely separated teeth; p5-7, *Balochisaurus* tilted subsquare or rectangle shaped proximal tibia. **Row 3**, p1, *Gspsaurus* lense shaped proximal tibia; p2, *Pakisaurus* proximal flat tibia; p3, comparison of proximal tibiae of *Pakisaurus* and *Gspsaurus*; p4,5, oval or parallelogram shaped distal tibiae of *Balochisaurus* and *Gspsaurus* respectively; p6, flat tibia of *Pakisaurus*; p7, flat tibia of *Sulaimanisaurus*. **Row 4**, p1, *Balochisaurus* humerus with anteriorly expanded radial condyle; p2, *Pakisaurus* humerus with anteriorly expanded radial condyle; p3, *Sulaimanisaurus* humerus without expanded radial condyle; p4,5, *Balochisaurus* proximal femora with rectangular cross section; p6, *Balochisaurus* femur with expanded head; p7, *Pakisaurus* distal scapula with short surface for coracoid articulation; p8, *Marisaurus* pubis with low and reduced pubis iliac symphysial part; p9, *Marisaurus* biconvex first caudal; p10, *Balochisaurus* biconvex first caudal; p11, *Balochisaurus* model.

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Biodiversity, Depositional environments and Age constraints for the intertrappean sediments associated with the Malwa Group of Deccan Trap

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The sediments at multiple stratigraphic levels associated with Malwa Group (Maastrichtian-Paleocene) of Deccan Traps were studied for the biota mainly the microvertebrates and palaeoenvironmental interpretation. The lava flows in the study area are associated with multiple intertrappean sedimentary beds and red/green boles at different stratigraphic levels in the lower part of the lava pile in Mandleshwar and Kalisindh formations. The intertrappean sediments are deposited at seven stratigraphic levels in the Deccan volcanic sequences and are exposed in 17 localities. The lake sediments vary in thickness between 2 m to over 4 m. These sediments are mostly represented by finely laminated siltstone, clays, shales/silicified shales, cherts, marls and limestones. Volcanic ashes/tuffs occur associated with sediments in some sections.

We investigated reptilian tetrapods from intertrappean sediments between the lava flows at different stratigraphic levels. Nearly 300 fossil bones were collected from wet-screened sediments which include fishes, frogs, turtles, crocodiles, lizards and dinosaurs. The turtles, crocodiles and lizards are recorded only at two stratigraphic levels in the lower most intertrappean sediments with distinct diversity. The angiumorph and scincomorph lizards are represented by dentary, maxilla, vertebrae and body scales occur in the lower most intertrappean. The new faunal assemblage recorded from Bharudpura, Bhagwanya, Ukala and other localities in the Malwa Plateau is of great importance for tracking biotic changes during Deccan volcanism and for stratigraphic correlation.

Associated marker Maastrichtian palynomorphs, diatoms and freshwater sponge spicules suggest that the Malwa palaeolakes were perennial, well oxygenated with low salinity and low water level. Stable carbon and oxygen isotope analysis of sediments and selected fossils like mollusc shells and ostracods show δ^{13}C value -6.1 and δ^{18}O -13.3 suggesting fresh water environments may be with intermittent brackish water-like conditions during the dry spells. The presence of crocodilian teeth also indicates the tropical condition during deposition.

The Malwa flows are the earliest and thickest Deccan lava flows. The presence of Maastrichtian palynomorphs, dinosaur bone and paleomagnetic analysis of the fauna bearing bracketing flows indicates depositions of sediments in Maastrichtian chron 30N.

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Earliest ant mimics - life history and evolution of Alienoptera

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Alienopteridae is among the most perplexing fossil insects and once important members of Cretaceous Dictyoptera (now including cockroaches, termites and mantises). It is presumed that Alienopteridae was important components of tropical Cretaceous terrestrial ecosystems, although the precise nature of its life history, evolution, and phylogenetic affinity remain controversial and open to debate (Bai et al. 2016, 2018; Kočárek 2018; Vršanský et al. 2018; Kočárek 2019; Wipfler et al. 2019; Hinkelman 2020; Sendi et al. 2020). Here we report new alienopterid nymphs from mid-Cretaceous Kachin amber (approximately 99 Ma) and define three nymphal morphotypes, along with proposed interpretations of their life style. The only species of the previously erected order Aethiocarenodea is identified as a junior synonym of morphotype I nymphs (in *Teyia*) of Alienopteridae (Poinar & Brown, 2017). We suggest that different strategies coping with predators or environmental stress had evolved in alienopterid nymphs. Geometric morphometric analyses suggest that morphotype I nymphs exhibit distinct morphological specializations that were most likely associated with ant mimicry, like immature stages of some modern crown mantises. Remarkably, mimetic association between these nymphs and stem-group ants provides the earliest record of ant mimicry (myrmecomorphy), which is contemporary with the earliest ants and their eusociality, and with the earliest evidence of myrmecophily. We discuss different interpretations of the life history of alienopterid adults, especially wasp mimicry, and conclude that *Teyia* was likely a wasp mimic. The nymphs (morphotype I) and adults of *Teyia* resemble different models, which provides the first fossil record of transformational mimicry, implying that this convergent syndrome had already evolved by the Early Cretaceous. In addition, one alienopterid nymph laden with pollen clumps provides evidence of gymnosperm pollination and a previously unknown gymnosperm-insect association. This is the sixth insect-pollinator lineage with Mesozoic gymnosperm associations. Extinct dictyopterans may have been among the earliest pollinators, with a hitherto undervalued role in pollination ecology (Figure 1). The greatly shortened forewings of Alienopteridae is an evolutionary trade-off between improved flight capacity and a more exposed (and hazardous) life history. Our phylogenetic analysis provides evidence that Alienopteridae and Umenocoleidae are sister groups and that the two families constitute a monophyletic group (Alienoptera) sister to Mantodea. Their main diversification probably occurred before the J/K boundary and their common evolutionary origin was probably during the Late Jurassic.

Figure 1. Ecological reconstruction of alienopterid nymphs. The brown insect at left with two cerci and the one on the Bennettitales (right rear) are Morphotype I, the other three brown insects are sphecomyrmine ants, anda camouflaged lacewing larva is preying on a non-mimetic alienopterid nymph (Morphotype III) in the background.

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Cretaceous gastropods from northern Myanmar: taxonomy and paleoecology

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Non-marine gastropods are important evidence and basic fossil materials for exploring Mesozoic biostratigraphy and palaeoecology. Gastropod fossils are abundant in northern Myanmar dating from the Cretaceous Period. The Mid-Cretaceous Burmese amber biota is one of the most diverse amber biotas in the world. Gastropod fossils are abundant and diverse, but few have been studied systematically. Based on 281 specimens, this thesis includes a systematic study of the overall composition of the gastropod inclusions with several important taxa; the study identified 7 families, 16 genera and 19 species (including 2 undetermined species), among which Cyclophoroidea comprise 11 genera and 16 species, accounting for about 84% of the total species; this indicates that the cyclophoroids may be the dominant group in the Southeast Asian land snail fauna during the Mid-Cretaceous. The discovery of new generic and specific taxa of cyclophoroids includes the earliest representatives of the families Cyclophoridae, Pupinidae, and Diplommatinidae, extending their range back to the Mid-Cretaceous (~99 Ma). This also includes the discovery of key fossil evidence for the colonization of the Family Hydrocenidae, whose stratigraphic range is extended by 13 million years. The first freshwater gastropod, *Galba prima* Yu , Neubauer and Jochum, 2021 (Lymnaeidae), is also reported from Burmese amber. The discovery of a freshwater snail on the Burma Terrane, then an island situated some 1500 km from mainland Asia, has implications for the dispersal mechanisms of Mesozoic lymnaeids, that is, airborne transmission (birds, pterosaurs, or storms), which may play an important role in the widespread distribution of this family in the Mesozoic. In addition to terrestrial and freshwater taxa, this thesis also describes two marine species and one unidentified species, namely *Mathilda* sp., *Acrocoelum myanmarina* sp. nov., and ?*Neodonaldina elongate*. Fossils of the families Matildoidae and Cimidae are widely distributed in the Mesozoic West Tethys Ocean. The discovery of amber fossils indicates that these two groups were widely distributed in the East and West Tethys. By analyzing the marine inclusions (ammonites, gastropods, etc.) in Burmese amber, it is possible to reconstruct the maritime palaeoenvironment of the Burmese amber forest in the Mid-Cretaceous: the climate was warm and humid, tropical storms occurring occasionally; there were temporary bodies of water in the forest, and the trees possibly grew alongside a coastal saline bay or estuary.

This thesis also discusses the palaebiology of cyclophorids in Burmese amber, including shell ornament, shell shape, opercula and excrement. The shell shape and opercula are very similar to living taxa, suggesting extreme morphological conservatism of Cyclophoroidea for nearly 100 million years. The hairy ornament is interpreted as increasing adhesion onto plants while grazing. Stronger adhesion would decrease the chance of falling off the leaf or stem up a tree. The development of a hairy periostracum, however, might also have been a survival strategy against predation. The Cretaceous greenhouse is renowned for its high sea levels and terminal extinction. We now have a better understanding of the non-marine as well as marine gastropod fauna of eastern Asia, including the survival of previously little-known groups.

Late Jurassic to Early Cretaceous Benthic Foraminifers of South Tibet, Tethyan Himalayas: Biostratigraphy, Palaeoecology, Palaeobiogeography

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In China, the marine Jurassic to Cretaceous Boundary is constrained to the sedimentary successions of South Tibet. Although most of the fossil groups of the Tethyan Himalayas have been studied for more than a century, foraminiferal researches were initiated in the past 20 years. Our work underlines the occurrence of different foraminiferal zones provisory named: (1) Textularia haeusleri; (2) Trochammina quinqueloba; (3) Pseudoreophax cisovnicensis, Globulina prisca; and (4) Lenticulina ouachensis, Textularia bettenstaedti assemblages zones. The J/K boundary is currently delineated since the base of the Shale Unit, Gucuo Formation. Indeed, the associated P. cisovnicensis, G. prisca Zone yields typical Early Cretaceous foraminifers. This result disagrees with previously published studies performed on ammonites, which indicated a latest Tithonian age for this part of the section. Therefore, the J/K Boundary was traditionally delineated in the middle to upper interval of the overlying volcanoclastic unit based on to the first occurrence of typical Valanginian to Barremian ammonite.

During the Late Jurassic to Early Cretaceous, South Tibet was located in the northern edge of India, South of Gondwana. The northern part of South Tibet was located in a deep marine environment, probably at bathyal to abyssal depths, whereas the southern part of South Tibet was part of the outer neritic shelf environment. Typical foraminiferal associations of mildly oxygen-deficient deep-water environment and increased surface productivity were recorded during the second half of the Early Cretaceous. Therefore, the Late Jurassic to Early Cretaceous global palaeogeographical changes strongly influenced the structure and composition of the recorded foraminiferal faunas. The composition of the benthic foraminiferal assemblages reflects a combination of Tethyan, North Atlantic, and local endemic faunal influences. Starting from the late Valanginian, the income of Proto-Atlantic and western Tethyan taxa in the northern margin of the Indo plate through the Trans-Gondwana Seaway, probably resulted from the enlargement and deepening of the Madagascar Channel, as well as the Mozambique and Weddell basins.

Tectonostratigraphy of the basement complex of Cebu Island, central Philippines: New constraints from petrography, micropaleontology and geochronology

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Contemporary views on the Early Cretaceous geology and tectonic history of Cebu Island in central Philippines comprehensively relied on data constrained from geochemical and geochronological studies of its volcano-plutonic units (Cansi Volcanics and Lutopan Diorite) (Deng et al., 2015; Deng et al., 2019; Deng et al.,2020; Gong et al., 2021). Tectono-magmatic interpretations suggests an island arc basement intruded by adakitic intrusive bodies produced during the initiation of Cebu island arc in an intraoceanic tectonic setting and isotopically involving both the Indian and the paleo-Pacific plates (Deng et al., 2020). However, recent data constrained from zircon grains extracted from xenoliths of the Cansi Volcanics and younger volcano-plutonic units in central Cebu suggests that these zircons were derived from the Eastern Indochina (Gong et al., 2021). Related studies regarding the overlying Late Cretaceous Pandan Formation also imply initiation of Cebu Island arc in a continental margin setting (e.g., oceanic leading edge of the Australian plate margin) (Rodrigo et al., 2020; Queaño et al., 2020). Other studies suggest that sedimentary and metamorphic blocks emplaced along the western margins of the Philippine Mobile Belt, including the Islands of Cebu and Bohol in the central Philippines, were perceived to be derived from the proto-South China Sea (Yumul et al., 2020).

Given these, recurring issues regarding the paleogeographic position and tectonic evolution of Cebu Island during the Cretaceous to Early Tertiary is still prevalent. This study looks into the timing of geological events particularly the basement complex of Cebu Island by means of zircon U-Pb geochronology and biostratigraphy (radiolaria, large, and small foraminifera). Specifically, the study focused on constraining the ages of the supposed Jurassic Tunlob Schist, Lutopan Diorite and the Pandan Formation and its associated carbonate units.

Field and petrographic studies revealed that the Tunlob Schist occur as blocks incorporated and/or adjacent to serpentinite diapirs and along fault structures transecting the Cansi Volcanics and Pandan Formation. It is predominantly composed of amphibolite, chlorite and quartz-sericite schists. Zircons extracted from the amphibolite schist in Cogon, Naga yielded a $^{238}U/^{206}Pb$ mean age of 120.42 ± 0.28 Ma. This is inconsistent to the earlier notion of its Jurassic age. Kernel probability density plots of 64 concordant zircon grains from this amphibolite show three interesting peaks around 125 Ma, 114 Ma, and 106 Ma, which could mean magma generation through partial melting of an amphibolite crust as source for the Lutopan diorite confirming Deng et al. (2019) theory on partial melting of an amphibolite oceanic crust. Compared to the typical adakitic hornblende- and quartz-rich Lutopan and Kansi diorites in Central Cebu, intrusive bodies found in Balamban and Minglanilla are granodiorite in terms of its composition. Petrographic analyses revealed hypidiomorphic granular and myrmekitic textures having abundant quartz, k-feldspars, plagioclases and hornblende. A $^{238}U/^{206}Pb$ mean age of 113.9 ± 0.39 Ma and 112.01 ± 0.39 Ma for the Minglanilla granodioite and 114.69 ± 0.31 Ma for the Balamban granodiorite reveal slightly older ages than the Lutopan, Carmen and Kansi diorites.

New field and paleontological evidence suggest that the overlying Pandan Formation occurs as accreted terranes backthrusted over the Cebu Island Arc. The Pandan Formation is comprised of blocks of bedded Middle Jurassic to Early Cretaceous radiolarian-bearing siliceous mudstones, admixtures of volcaniclastics and Early Cretaceous limestone olistoliths (Tuburan Limestone), Campanian to Late Maastrichtian Globotruncana-bearing calcareous siltstones-lime mudstones, turbiditic sandstones-siltstone, calcareous siltstones and lime mudstones with Middle Paleocene to Late Eocene planktonic foraminiferal assemblages and Early Oligocene limestone olistoliths (Lutak Hill Limestone and Baye Formation). Youngest zircon grains extracted from three turbiditic sandstones from Tuburan, Camp 4 Minglanilla, and Pandan, Naga revealed $^{238}U/^{206}Pb$ maximum depositional ages of 70.5 ± 2.8 Ma, 86.5 ± 5.4 Ma and 80.0 ± 1.8 Ma. In the Tuburan area, the oldest zircon grain dated is at 235 ± 4 Ma with zircon peaks at Late Triassic, Middle to Late Jurassic, Early Cretaceous and highest peak at Late Cretaceous. In Pandan in Naga, the oldest age dated is 1977 ± 14 Ma with zircon peaks from Early Devonian, Permian, and Middle to Late Triassic, highest peak at Middle Jurassic, and Early to Late Cretaceous zircons. Among the three representative samples, zircon grains extracted from Camp 4 Minglanilla sandstone directly overlying the volcaniclastics and Early Cretaceous limestone olistoliths revealed Early to Late Cretaceous zircons.

Based on the preliminary data we gathered, we interpret that the volcano-plutonic basement of Cebu Island was formed independently as an island arc during the Early Cretaceous and collided with continentally derived fragments (proto-South China Sea fragments) sometime during the Early to Middle Oligocene and are represented by the Pandan Formation accreted terranes.

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Age, geochemistry and isotopic signatures of granitoids in northern Palawan, Philippines

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The Palawan Continental Block, a sliver of the southwestern Eurasian margin that was translated during the opening of the South China Sea (SCS) basin, contains granitic intrusive bodies that reveal Yanshanian magmatism signatures. Previous works in northern Palawan Island only show Cenozoic intrusive units (i.e., Late Eocene Central Palawan Granite and the Middle Miocene Kapoas Granitoid) despite it's known association with the southeastern Eurasian margin. The presence of Mesozoic igneous rocks can only be observed in the basins surrounding the South China Sea region (e.g. Pearl River Mouth Basin, Xisha Block, Zhongsha Block, Nansha Block, and the Schwaner Mountains in Borneo). This study investigated the Daroctan Granite observed in the northern portion of Palawan mainland and was assigned a Cretaceous age based on stratigraphic correlation. The Daroctan Granite was not included in recent works and was only mapped as part of the Mesozoic mélange. The well-studied Middle Miocene Kapoas Granitoid was also included in this study in terms of geochemistry and isotopic signatures.

Geochronological analysis using monazite CHIME dating yielded Late Cretaceous age for the Daroctan Granite. The geochemical and isotopic signatures of the Daroctan Granite was compared with samples from the Central Palawan Granite and the Kapoas Granitoid. The granitoids in northern Palawan are composed of biotite granodiorite and biotite granites and are geochemically characterized as high-K calc-alkaline, intermediate I- and S-types, and peraluminous. The geochemistry of both intrusive units shows distinct similarities which suggest the same source materials. The Sr and Nd isotope values of the Kapoas Granitoid plotted below the field of the South China Sea sediments while those from the Daroctan Granite plotted higher than that of the South China Sea sediments. The initial isotopic ratio of the Daroctan Granite is within the range of those reported from the granitic rocks surrounding the South China Sea.

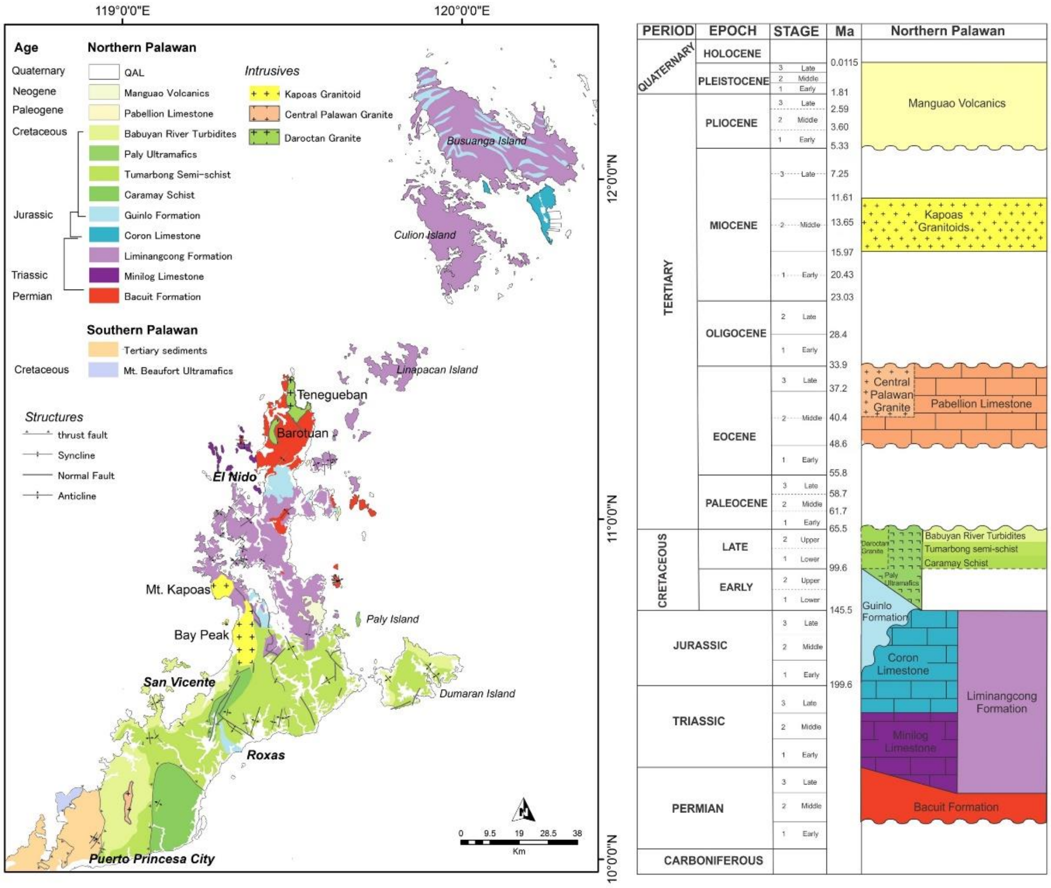

Figure 1 Geology and stratigraphic column of northern Palawan (modified from Mines and Geosciences Bureau and MMAJ-JICA, 1988).

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Unroofing of an island arc: Clues from the Pandan and Malubog Formations, Cebu island, Philippines

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The oldest rocks within the Philippine Mobile Belt are found in Cebu Island in Central Philippines. These include the volcanic arc rocks of the Cretaceous Cansi Volcanics, the intrusive bodies of the Cretaceous Lutopan Diorite and the sedimentary sequences of the Late Cretaceous to Early Oligocene Pandan Formation. These Mesozoic units are overlain by the Late Oligocene to Early Miocene Malubog Formation. Both the Pandan and Malubog Formations preserve records of how this part of the Philippine island arc system evolved. This paper presents the geochemical signatures of these sedimentary sequences to decipher the provenance, tectonic setting, paleoweathering and paleoclimatic conditions recorded in these clastic units.

The Pandan Formation is made up of poorly sorted subhedral to euhedral clasts of lithic volcanic fragments and detrital mafic minerals. Major oxide and trace element compositions indicate derivation from mostly mafic to intermediate igneous sources in an oceanic island arc setting. Sandstones of the Malubog Formation are dominantly made up of detrital plagioclase and monocrystalline quartz grains. Whole rock geochemistry suggests mafic, intermediate and felsic source rocks in an oceanic island arc setting for the Malubog Formation. The Pandan Formation samples have an average CIA value of ~50 consistent with derivation from relatively fresh or unweathered source rocks. The CIA values for the Malubog Formation samples are slightly higher (average is ~65) suggesting that the source rocks are more weathered compared to the source rocks of the Pandan Formation.

Geochronological dating (U-Pb) of detrital zircons from these sedimentary sequences revealed a magmatic age peak at 112.6 ± 1.5 Ma (late Early Cretaceous) for the Pandan Formation. For the Malubog Formation, 3 peaks are identified from the age spectrum - 119.9 ± 3.7 Ma (Early Cretaceous), 32.7 ± 0.26 Ma (Early Oligocene) and 27.2 ± 0.75 Ma (Late Oligocene).
The integrated petrographic, geochemical and geochronological data from the Pandan and Malubog Formations suggest unroofing of island arc materials from Late Cretaceous to Early Miocene. Relatively dry or arid paleoclimatic conditions prevailed during this period to account for the weak weathering recorded in the low CIA values.

Magnetism and geochemistry at the Jurassic-Cretaceous and Cretaceous-Paleogene boundary transitions

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Multidisciplinary research of Jurassic-Cretaceous (J/K; Tithonian-Berriasian) and Cretaceous-Paleogene (K/Pg) boundaries is being carried out at the Paleomagnetic laboratory of the Institute of Geology of the Czech Academy of Sciences in order to contribute to designation of the last boundary between stratigraphic periods (J/K) not yet defined by the International Commission on Stratigraphy as well as reveal magnetic signature and find evidences of possible warming–extinction phases connected to K/Pg event.

The carbonate sequences from several classic and new J/K localities from Czech, Slovakia, Poland, Austria, France and Serbia are intensively studied, with large emphasis on magnetostratigraphy. The Silesian Unit (at Ropice, Goleszow, etc.) is often found in river-cuts or abandoned quarries, where the slope marlstones and pebbly mudstones (Vendryně Fm.) with overlying calciturbidites (Těšín Limestone Fm.) are exposed around expected J/K transition. At Snežnica, the Tithonian-Berriasian hemipelagic limestones within 300 m thick succession are exposed. The late Tithonian to late Berriasian limestones of the Oberalm Fm. are exposed at the Rettenbacher quarry (Fig.1A) in Northern Calcareous Alps.

The K/Pg research focuses on Czech and Slovak Outer Carpathian sections (including sub-CCD facies) with the emphasis on local magnetic and paleoenvironmental variations within global K/Pg event. The Magura Unit (Soláň Fm.) is exposed at Uzgruň stream-cut locality (Fig.1B) where the 16 m thick continuous composite section, combined from four turbidite subsections in individual tectonic slices, is found. The Upper Maastrichtian - Lower Paleocene strata of the Silesian Unit are exposed at isolated silty mudstone outcrops within Bukovec section. The two studied drilled sections comprise Late Cretaceous to Early / Middle Eocene formations for Žilina and Kršteňany drill cores, respectively. K/Pg in Žilina (ZA-1) 75 m drill core is developed in bathyal environment, while 250 m thick Kršteňany (KRS-3) drill core consists of terrestrial to marine facies.

The methodology combines rock magnetic and paleomagnetic investigations, such as studies of magnetic susceptibility and its' anisotropy, natural remanent magnetization and its' alternating field (AF) and temperature (TD) demagnetization, and isothermal remanent magnetization (IRM); with geochemical analyzes (Hg, TOC, etc.) and biostratigraphy. Results indicate that although the magnetic susceptibilities and remanent magnetization vary within studied J/K and K/Pg localities, in average mostly paramagnetic signal with occasional higher magnetic susceptibility is observed. Assessment of magnetic mineralogy has revealed that magnetic properties are carried mainly by magnetite and occasionally also by higher coercive magnetic fraction, such as hematite. The mercury analysis indicates also variations among different localities. Hg data reveal, for example, in ZA-1 drill core two enhanced Hg peaks (Late Maastrichtian and Early/Mid-Danian) probably due to higher input of volcanogenic Hg. Variations in magnetic properties and geochemistry can be related to paleoenvironmental changes.

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Figure 1: Sampling of (A) J/K locality at Rettenbacher, Austria; and (B) K/Pg locality at Uzgruň, Czech Republic.

Magnetostratigraphy and micro-biostratigraphy of the Berriasian stage at Berrias locality

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The detailed magnetostratigraphic and micropaleontological investigation on the Jurassic/Cretaceous (J/K) boundary aims to precisely determine the boundaries of magnetozones and narrow reverse subzones, and find global correlation across the J/K boundary. One of studied localities is the Berrias limestone-, marly limestone- and marl succession section in France. Berrias, 30 m thick, section is considered to be a historical type locality of the Early Cretaceous Berriasian stage (Galbrun & Rasplus, 1984; Glabrun, 1985). The section has been well described and published, and covers the majority of the stage (Jacobi, Occitanica and Boissieri ammonite zones). However, so far, the stage base has not been reported. Therefore, the calpionellid biostratigraphy was recently revised and a paleomagnetic study (magnetostratigraphy; e.g. to revise anomalous magnetozone M16n1r) is being carried out.

The base of the Calpionella Zone, Alpina Subzone has been fixed by the BWG to be the primary marker for the J/K boundary. A precise biostratigraphic calibration of calpionellid bioevents with first occurrences (FOs) of nannofossil marker species provides the crucial data. Calcareous nannofossils provide poorly preserved assamblage with low abundances, dominated by ellipsagelosphaerids (genera *Watznaueria* and *Cyclagelosphaera*, making up more than 60 % of specimens) and *Nannoconus* sp. (on average 30 % of the assemblage). Important bioevents have been observed, namely first occurrences of *Nannoconus steinmannii minor*, *N. kamptneri minor*, *N. steinmannii steinmannii* and *N. kamptneri kamptneri*. *Nannoconus wintereri* and *N. globulus minor* are present across the studied section. The sequence spans a stratigraphic range from the nannoplankton Zone NC0 to the Zone NC1 *sensu* Casellato & Erba (2021), documenting Early Berriasian age.

Due to magnetic field polarity changes occurring simultaneously around the entire globe, the high resolution magnetostratigraphy is one of the most efficient tools for J/K boundary correlation. The magnetostratigraphy in Berrias section, indicates presence of 4 normal and 4 reversed polarity zones as well as several short subzones, probably including M16n1r. The base of the section shows zonation from M19n up to M17r. The interpretation of this part of the section is straightforward, however the magnetostratigraphic interpretation of the upper part of Berrias section needs more careful consideration. To reveal information about carriers of remanent magnetization, e.g. distinguish between primary magnetite, primary or diagenetic hematite and goethite (weathering product), for better magnetostratigraphic interpretation, the rock magnetic analyses are carried out.

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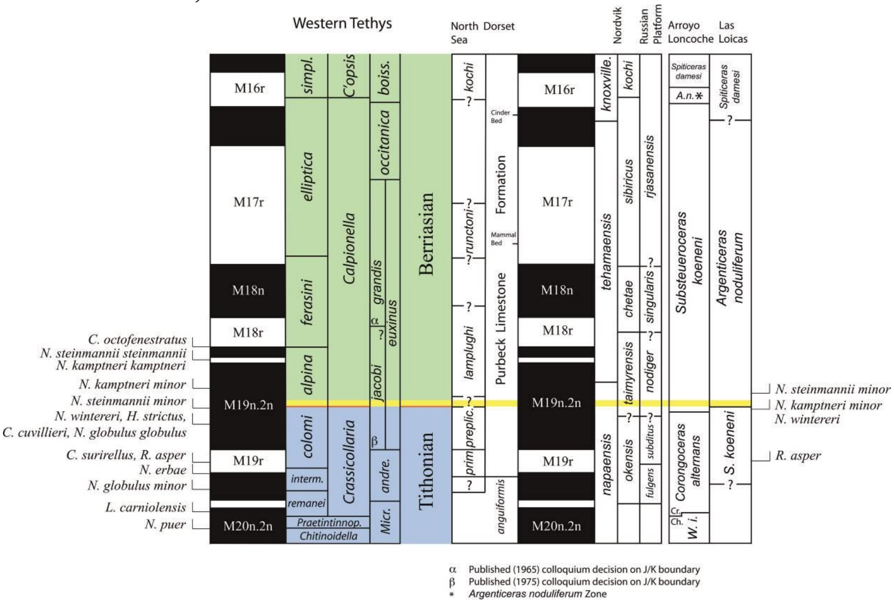

Fig. 1. Stratigraphic chart for J-K boundary interval prepared by Berriasian Working Group, published by Wimbledon (2017).

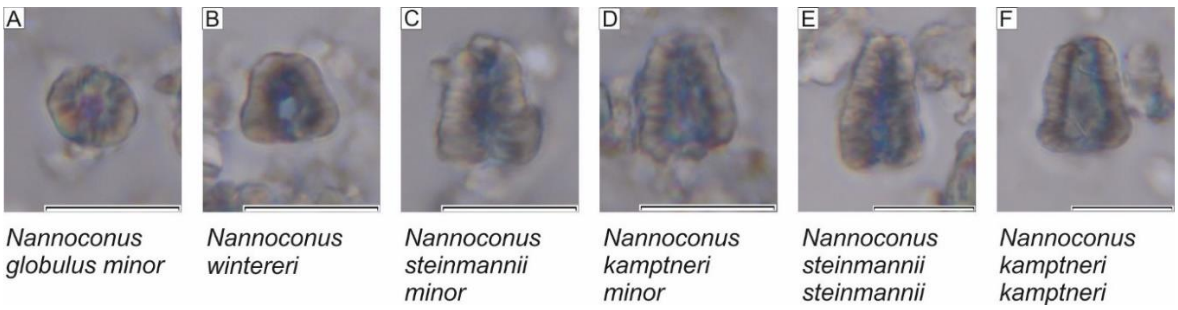

Fig. 2. The most important biostratigraphic markers of calcareous nannofossils across the Jurassic-Cretaceous transition. Berrias section, plane polarized light. Scalebar represents 10 µm. A) *Nannoconus globulus* subsp. *minor* Bralower *in* Bralower et al., 1989; sample B 24. B) *Nannoconus wintereri* Bralower & Thierstein, in Bralower et al. 1989; sample B 25. C) *Nannoconus steinmanni* subsp. *minor* Deres and Achéritéguy 1980; sample B 47. D) *Nannoconus kamptneri* subsp. *minor* (Brönnimann, 1955) Bralower *in* Bralower et al., 1989; sample B 47. E) *Nannoconus steinmanni* subsp. *steinmannii* Kamptner, 1931; sample B 48. F) *Nannoconus kamptneri* subsp. *kamptneri* Brönnimann, 1955; sample B 47.

The Renaissance of the oldest Pacific sediments: Trans-Pacific records of co-evolution of geochemistry, marine ecosystem, and sediment lithology in the pelagic realm

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The Pacific Ocean has been the largest ocean during the Mesozoic and Cenozoic and contains various types of sediments on the seafloor. Previous studies focused mainly on carbonate-bearing sediments to discuss the oceanic, biological, and geochemical evolution. However, chert and pelagic clay also have comparable, or complementary, information to that of carbonate. Radiolarians in chert were the main component of the pelagic siliceous sediments during the Mesozoic, and their diversity should have reflected local to global environmental changes. Recent studies on pelagic clay discovered that transient increase of the fish debris (teeth/bones) accumulation occurred repeatedly in the Pacific Ocean. For the complete understanding of the oceanic and biological evolution since the Mesozoic, it is essential to utilize the chert and pelagic clay as well as carbonate.

This proposal aims to recover the latest Jurassic to Cenozoic sediments on the Pacific abyssal plain and around Shatsky Rise. Our primary objectives are (1) to elucidate the changes in marine biota across the Jurassic-Cretaceous boundary (JKB), (2) to understand the long-term transition from a Mesozoic chert-rich ocean to a Cenozoic chert-poor ocean including a change in diversity of radiolarians, and (3) to decipher the environmental change recorded as an enrichment of fish-remains, and rare-earth elements and yttrium (REY), in the pelagic clay during the Late Cretaceous and Cenozoic.

To study the turnovers of marine biota at pelagic sites in the Pacific Ocean across the JKB, both siliceous and calcareous fossils are required to be preserved. A promising sediment succession across the JKB could exist underneath the seafloor at the middle flank of Shatsky Rise (Site SR; nearby ODP Site 1213). To investigate the transition from a Mesozoic chert-rich ocean to a Cenozoic chert-poor ocean, it is critical to confirm the boundary layer from the chert/silica-rich sediments to the clayey/silica-poor sediments and to elucidate factors (e.g., environmental changes and/or physicochemical processes during early diagenesis) that caused the lithological transition. Based on the bulk geochemical data, the revisit of DSDP Site 198, north of Minamitorishima Island, can recover the transition. To verify the relationship among the enrichment of fish remains (or REY), paleoceanographic conditions, and geochemical cycles, a complete set of pelagic clay of the Cretaceous to Paleogene is required. For these purposes, we propose drilling the southern foot (Site SR) of Shatsky Rise, and north of Minamirtorishima (Site MM).

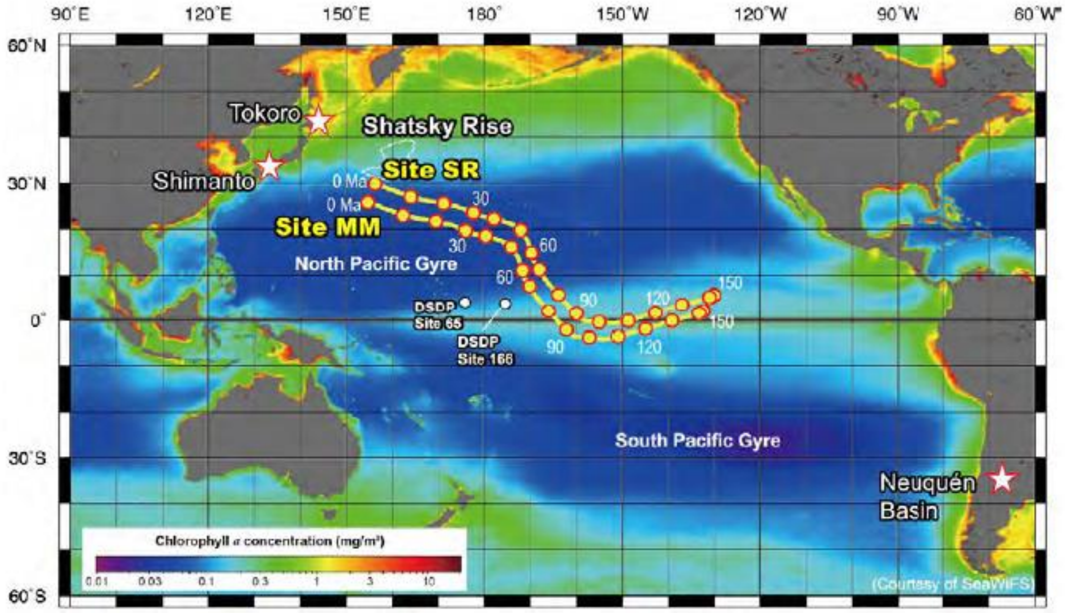

Figure 1 Reconstructed track of the proposed sites. Yellow circles indicate paleopositions of the proposed sites in 10-million-year steps, with numbers showing the age in million years ago. The reconstruction was created by using GPlates software (http://www.gplates.org) based on the plate polygon and rotation data by Matthews et al. (2016). Background is modern global sea-surface chlorophyll *a* concentration (courtesy of SeaWiFS Project, NASA). White stars indicate terrestrial sections, Tokoro and Shimanto belts in Japan and Neuquén Basin in Argentina, that relate to the trans-Pacific records which this proposal targets.

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Upper Mesozoic stratigraphy of northeastern China, Mongolia and Russian Far East (Sikhote-Alin and Transbaikalia): non-marine and marine correlations

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Upper Mesozoic (Upper Jurassic and Cretaceous) rocks are widely distributed on the territory of northeastern China, Mongolia and Russian Far East. In Sikhote-Alin, the Upper Jurassic and Lower Cretaceous rocks are represented mainly by marine deposits, whereas the Upper Cretaceous rocks are mainly volcanic and non-marine sedimentary-volcanic. In northeastern China, Transbaikalia and Mongolia the upper Mesozoic rocks are, on the contrary, mainly non-marine. Fully marine Upper Jurassic–Valanginian deposits are restricted to the northeastern of Heilongjiang Province (China) near the border with Russia. Barremian–Albian non-marine deposits alternating with marine ones also occur in this region. They contain marine and non-marine fauna and, therefore, represent an important object for non-marine and marine correlation.

The upper Mesozoic rocks of northeastern China, Mongolia and Russian Far East are of high scientific interest because they contain coal and oil (economic aspect), yield exceptionally well-preserved terrestrial fauna in China (Jehol Biota), remains of dinosaurs and other Mesozoic terrestrial fauna and flora including first angiosperms in Mongolia, China and Transbaikalia (palaeobiological aspect). Also, the presence of marine and non-marine fauna in the upper Mesozoic deposits of northeastern China allows correlating non-marine successions of China and adjacent regions with marine successions of Sikhote-Alin and therefore with the International Stratigraphic Chart based on marine fossils (stratigraphic aspect). However, there is still no generally accepted correlation scheme for the upper Mesozoic deposits of these regions. The reason for this is the difficulty of using of strata of the International Chart based on marine fossils for subdividing and correlation as well as the lack of generalizing works on the stratigraphy and geology of the upper Mesozoic deposits of this region that includes the territories of three countries. The solution to this problem is the generalization of information on the stratigraphy and palaeogeography of the Upper Jurassic and Cretaceous deposits and the stratigraphic distribution of the most important groups of fauna and flora in northeastern China, Sikhote-Alin, Mongolia and Transbaikalia.

The stratigraphy of the Lower Cretaceous of Sikhote-Alin is well studied (Turbin, 1994; Markevich et al., 2000; etc.) as well as the most significant for stratigraphy and correlation groups of fauna and flora (bivalves *Buchia* and *Aucellina*, inoceramids, ammonites, flora, microphytofossils); stratigraphic horizons (=regional stages) are established allowing the correlation of deposits from different structural-facial zones (Turbin, 1994). The intervals of transgressions and regressions are also determined (Markevich et al., 2000). Upper Jurassic (Volgian)–lower Hauterivian are widely distributed in Sikhote-Alin and characterized by bivalves *Buchia* and ammonites. They are well correlated with marine rocks of northeastern China based on distribution of *Buchia* (Sha et al., 2009; Kosenko et al., 2021a). Upper

Hauterivian and most of Barremian are absent in Sikhote-Alin that is explained by the regression of sea. Non-marine upper Hauterivian and Barremian deposits are known only in the south of Primorye (lower part of the Suchan and Nikan groups) and characterized by remains of flora. Aptian–Albian deposits are widely distributed in Sikhote-Alin and characterized by bivalves *Aucellina*, inoceramids and ammonites. The middle Albian is characterized by beds with trigoniids and acteonellids. Numerous localities with flora remains that include first angiosperms are known in Southern and Western Primorye. This stratigraphic interval is the most perspective for non-marine and marine correlations. The region covering the adjacent territories of Russia and China is the most significant for non-marine and marine correlations. Barremian(?)–Albian deposits are characterized by marine and non-marine mollusks as well as flora remains that allows to clarify the age of non-marine fossils. The Assikaevka Formation of Western Sikhote-Alin is correlated with the Dajiashan, Longzhaogou and Jixi groups of northeastern China; the Alchan Formation is correlated with the Huashan Group (Kosenko et al., 2021b). The Jixi Group yields the elements of the Jehol Biota and therefore is correlated with the Jehol Group (Sha, 2007). Based on the distribution of non-marine fossils the Lower Cretaceous deposits of northeastern China are correlated with the Lower Cretaceous rocks of Mongolia and Transbaikalia. The most significant for correlation is the *Ephemeropsis – Eosestheria – Lycoptera* assemblage represented by typical elements of the Jehol Fauna. Based on the presence of this assemblage the Turga Formation of Transbaikalia is roughly correlated with the Shinekhudag and Tsagaantsav formations of Mongolia; the upper part of the Turga Formation is correlated with the Shinekhudag Formation and the Jehol Group (excepted the Fuxin Formation). Coal-bearing Khukhteeg Formation completing the section of the Lower Cretaceous in Mongolia is correlated with coal-bearing Kutin Formation of Transbaikalia and with the Fuxin Formation of the Jehol Group in northeastern China. Despite the possibilities of rough correlation of the Upper Jurassic and Lower Cretaceous deposits of Mongolia, Transbaikalia and northeastern China some problems are still needed to be resolved. In northeastern China elements of Jehol Fauna are not found in deposits older than the Yixian Formation (Barremian–Aptian) (excepted for *Ephemerospis trisetalis*, *Peipiaostheus*, *Yanjiestheria*, *Cypridea*) (Li et al., 1994). However, in Mongolia elements of the Jehol Fauna (*Lycoptera middendorfii*, *Eosestheria middendorfii*, *Probaicalia gerassimovi*, *P. vitimensis*, *Psittacosaurus*) are known from the Tsagaantsav Formation considered as Berriassian–Valanginian in age (Shuvalov, 1980). Thus, the question arises either in the correctness of the age of the Tsagaantsav Formation or in the age of the lower boundary of the stratigraphic distribution of the elements of the Jehol Fauna outside northeastern China. The other problem is the correlation of the Upper Cretaceous rocks of Sikhote-Alin, northeastern China and Mongolia. The Upper Cretaceous rocks are much less distributed compared to the Lower Cretaceous ones. Moreover, the palaeogeographic conditions of their sedimentation is rather different. This led to great difference in the faunal and floristic characteristics of the Upper Cretaceous sedimentary strata in Sikhote-Alin, northeastern China and Mongolia. The solution to the problem of correlation of the Upper Cretaceous sediments of Sikhote-Alin, China and Mongolia should primarily be based on a comparison of floral and spore-pollen complexes.

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Angiospermerous fossil-bearing lacustrine deposits in an Early Cretaceous floodplain in South Korea: fossil occurrences and paleobiological implications

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The paleoenvironments, taphonomy, and paleoecology of plant fossil-bearing beds in the uppermost part of the Early Cretaceous (Aptian–Early Albian) Hasandong Formation, Jinju City, South Korea, were studied. The plant fossil beds occur in fluvial plain deposits including lake deposits. The plant fossils are preserved in lacustrine deposits, and most of them are compressed and carbonized. They include leaves, cones, and seeds of conifers; twigs; the outer parts of flowers; and bark fragments. This study reports the first discovery of angiospermerous macrofossils from the Early Cretaceous in South Korea, which is also the first discovery of angiospermerous macrofossils in the region of Asia below 40° N. From the results, it is likely that a small oasis surrounded by a nearly sterile floodplain existed in the Early Cretaceous in the Korean Peninsula under a semiarid paleoclimate. The oasis provided an active ecosite, akin to a modern savannah area, and a habitat for sparse angiospermerous vegetation beneath a canopy of conifers. The first appearance of Korean angiospermerous plants in the lake margin deposits suggests that the early angiosperm habitats were freshwater lake and wetland habitats. This study provides new information that advances the understanding of the vegetation conditions and environments associated with early angiosperm evolution.