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A FOSSIL SPIDER FROM THE CRETACEOUS OF KOREA

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ABSTRACT—A fossil spider from the Cretaceous Jinju Formation of Korea is redescribed as *Korearachne jinju*, n. gen. n. sp. Previous description of this specimen, the only known fossil spider from Korea, was inadequate, and here we present a more detailed interpretation and illustration of the specimen. The fossil spider is preserved alongside juvenile albuiform fish, Diptera and possible crustaceans, which suggests a mass mortality event. Familial identification of the spider is impossible, but it probably belongs to a guild of wandering spiders, possibly lycosoids.

INTRODUCTION

KIM AND Nam (2008) briefly described the first fossil spider from Korea, from the Cretaceous Jinju Formation, as a male *Pisaura*. Together with a rather poor illustration, they gave no description apart from a body measurement of 7 mm and a leg formula of 1423. Through the kindness of the second author, and the help of the third, the specimen was transported to the University of Kansas, where detailed description, drawings and photographs were made. In this paper, we give more detailed description and interpretation of the single known specimen, as well as further detail about the stratigraphic occurrence and paleoecology. Fossil spiders are very rare, especially in rock rather than amber, and so this unique occurrence of a fossil spider from Korea is worthy of detailed description. It is impossible to assign the specimen to a family, but its characteristic long walking legs, which are highly setose but show only sparse macrosetae, are distinctive.

GEOLOGICAL BACKGROUND

The Gyeongsang Supergroup contains non-marine Cretaceous deposits widely distributed in the southeastern part of the Korean Peninsula. The spider fossil was discovered in the Jinju Formation (=Dongmyeong Formation) in the Sacheon region (Guho-ri Chookdong-myeon, Sacheon-si, Gyeongsangnam-do) located in the southwestern part of the basin (Fig. 1) (Kim and Nam, 2008). The Jinju Formation is a lacustrine deposit consisting of black shale, light gray arkose, and greenish gray sandy shale. The fossil was found in black shale in the upper part of the Formation. This member is characterized lithologically by thick, fine-grained, dark shale beds, representing a marginal lacustrine depositional environment (Lee and Yang, 1990; Son, 1990) (but see Discussion).

The Jinju Formation is the youngest stratigraphic unit in the Shindong Group which ranges from Hauterivian to Albian, based on studies of freshwater mollusks, ostracodes, Charophyta and pollen grains (Chang, 1975; Choi, 1985, 1989; Seo, 1985; Kimura, 2000; Yang, 1982). Until recently, the Jinju Formation could not be dated precisely due to the lack of age-diagnostic fossils, but it was assumed that the Formation is no older than Barremian and no younger than early Aptian (Yi et al., 1994; Doh et al., 1994). More recently, however, Hayashi (2006) has dated the Jinju Formation to Barremian on the basis of ostracode faunas. The Jinju Formation yields plants, ostracodes, bivalves, conchostracans, insects, fishes, rod-shaped stromatolites, dinosaur bones and tracks, and pterosaur teeth (Baek and Yang, 2004; Paik, 2005; Yun and Yang, 2001). Among these fossils, the palynofloras from the Formation suggested that an arid and warm climate was prevalent in the region during the early Cretaceous (Choi, 1985). Tectonostratigraphic and paleogeographic research into Lower Cretaceous terrestrial basins in East Asia also suggests subtropical-tropical conditions with frequent desiccation in the Korean mainland at that time (Haggart et al., 2006). Fish fossils from the spider locality and nearby outcrops—juvenile and adult elopiform and albuliform teleosts which today are primarily marine—suggest that the environment of deposition of the Jinju Formation was in close connection to the sea (Yabumoto et al., 2006). The Shindong Group was deposited in the Nagdong Trough, a half-graben which separated the South China Block (on which Korea was situated) to the west, and to the east a fault-bounded, tectonically active block which is now present-day Japan (Lee and Lee, 2000; Hisada et al., 2008).

MATERIAL AND METHODS

Material.—The spider is preserved in a finely laminated, very dark gray shale. The bedding plane surrounding the fossil is richly fossiliferous with insects (mainly Diptera), fish (juvenile Albuloidei), and an abundance of small, curved organisms which could be crustaceans (Fig. 2). The specimen described here, TSH-0808 (part only, no counterpart), is held in the collections of the Natural Heritage Center of Korea.

Methods.—Photomicrographs were made using a Canon 5D Mark II digital camera on a Leica MZ16 microscope with the specimen under alcohol and using a polarizing filter to enhance contrast. Numerous photographs were taken at high magnification and assembled into a collage using Adobe Photoshop. Drawings were prepared using a drawing tube on the microscope and by tracing from photographs with Adobe Illustrator. All measurements are in mm, and were made using Photoshop.

Abbreviations used on the figures.—1, 2, 3, 4=leg numbers; ch=chelicera; cx=coxa; fe=femur; mt=metatarsus; op=opisthosoma; pa=patella; Pd=pedipalp; st=sternum; ta=tarsus; ti=tibia; tr=trochanter.

INTERPRETATION OF THE FOSSIL

Only the prosoma is preserved; there is no trace of the opisthosoma except for a paler area with an outline which could possibly mark the lateral opisthosomal margin, but there are many, similar lighter patches in this rock which resemble the pale area, and the patch does not show the setation present over the rest of the body. The body length

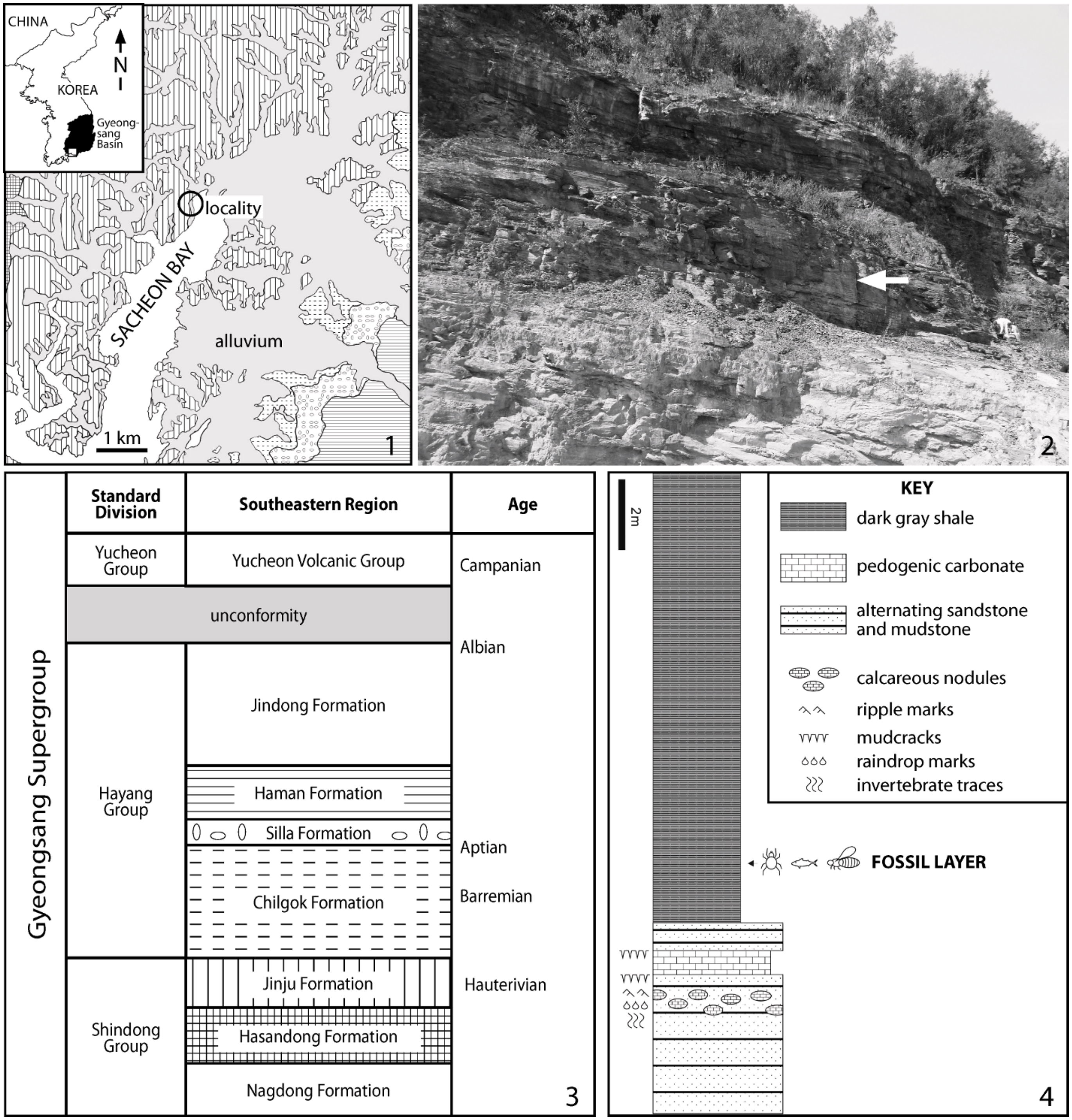

FIGURE *1*—Location map, photograph, geological map, and stratigraphy of the Jinju Formation of the Gyeongsang Basin, Cretaceous of Korea. *1*, location map of the fossil locality on Sacheon Bay; *2*, photograph of the locality, arrow points to fossiliferous horizon; *3*, stratigraphy of the Gyeongsang Supergroup; *4*, sedimentary log of the locality.

measurement of 7 mm given by Kim and Nam (2008) is only realistic if the opisthosoma is estimated.

The walking legs are clearly defined, and clothed in fine setae, but there is sparse evidence of macrosetae, which would be expected to be seen clearly in this type of preservation. At first sight there appear to be none, but Darrell Ubick (pers. commun., 2011) spotted some possible macrosetae lying along the axes of tibiae and metatarsi of legs 1 and 2. This disposition, and the fact that none are seen breaking the outline of the podomeres, suggests they would have been adpressed against the podomere surface in life. The metatarsus of leg 4 shows no signs of a calamistrum, which would be clearly visible as a line of bristles, so the spider is considered to be ecribellate. The distal end of the tarsus is seen only on left leg 2, where the claws are poorly visible, though a small, median claw appears to be present.

At first glance, the left and right pedipalps appear odd, with that on the left appearing to have a bulbous tarsus, while that

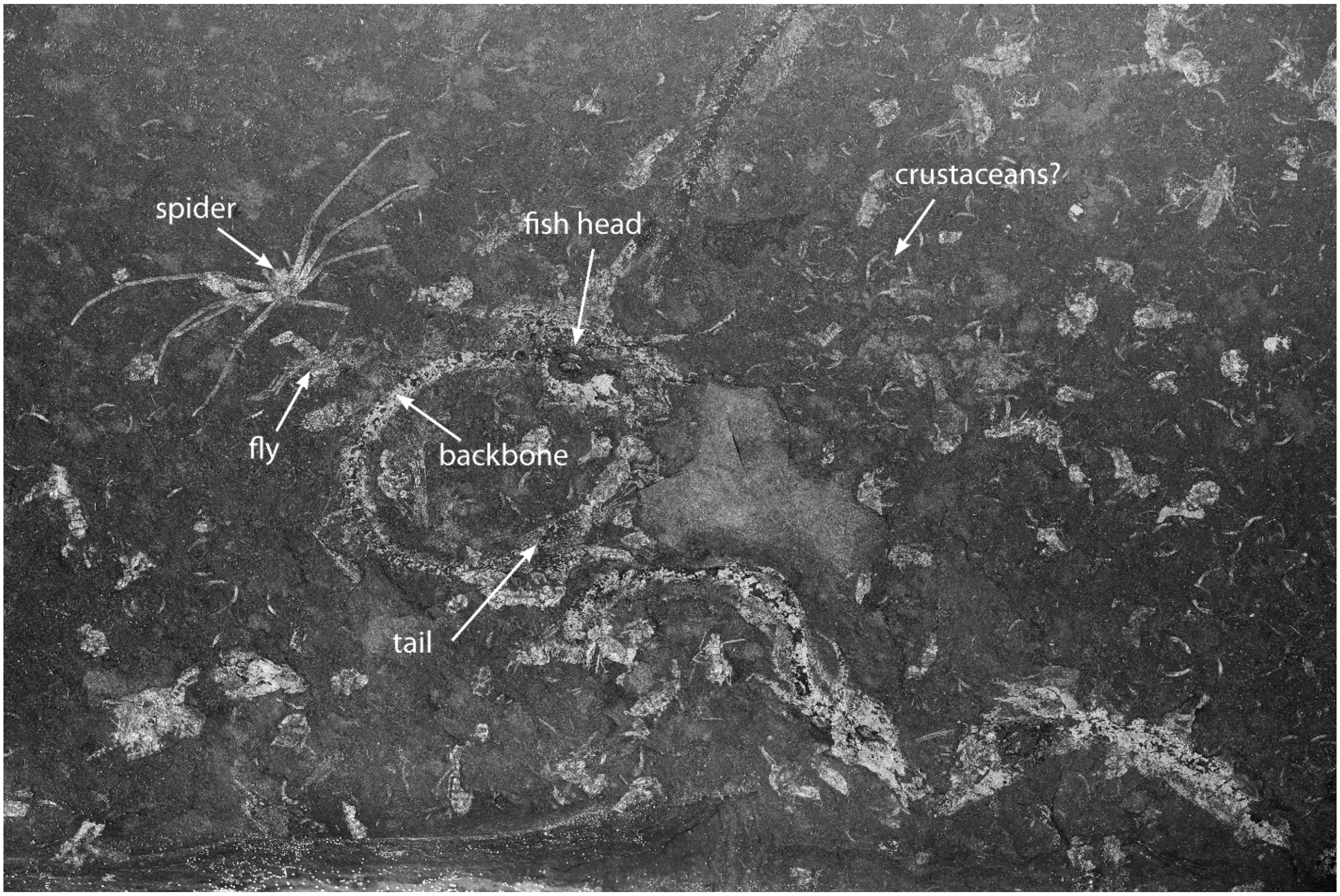

FIGURE 2—General view of the shale slab bearing the fossil spider, to show associated fauna: juvenile albuliform fish, Diptera, and ?crustaceans, suggestive of a mass mortality.

on the right is slender. Kim and Nam (2008) described this specimen as a male, presumably because the left pedipalp appears inflated as in an adult male. However, close inspection of the setal pattern reveals that on the right, the setae diverge forwards, i.e., distally, while on the left the setae can be seen to diverge backwards, hence the left pedipalp is flexed backwards, and its tarsus can be seen to overlie the coxa of the left first leg. The pedipalp tarsi are narrow and clearly not those of an adult male. We therefore interpret the specimen as a female or juvenile.

Between the pedipalps is a large area of fossil that appears bilobed anteriorly, with a few setae in the rock matrix forward of that. This area represents the chelicerae and clypeus. Chelicerae are preserved in a variety of ways in fossil spiders, depending, in part, on the disposition of the chelicerae in life. Large, porrect chelicerae normally extend forwards on compression, small chelicerae may simply crush vertically, while a backward rotation of the distal end of the chelicerae occurs in other spiders. It was this last taphonomic artifact which led Petrunkevitch (1922) to erect the fossil family Parattidae, based on its unusual eye arrangement. Further study (Selden and Penney, 2010) has shown the parattid eye pattern is that of a lycosoid deformed by the backward rotation of the chelicerae during compression. The row of setae forward of the bilobed area in the Korean fossil suggests it is part of the carapace, i.e., the clypeus, and that the chelicerae are rotated backwards, as seen in the parattids. Alternatively, but less likely, the chelicerae would be large, porrect, and setose.

Two pale areas posterior to the chelicerae are interpreted as the pedipalp coxal endites. Coxae can be seen at the bases of the walking legs on the right side; they are less well visible on the left. The proximal ends of the coxae help to demarcate the shape of the sternum, which appears to be suboval or subcordate in outline. Thus, the specimen presents a ventral aspect.

SYSTEMATIC PALEONTOLOGY

Order ARANEAE Clerck, 1757
Suborder OPISTHOTHELAE Pocock, 1892
Infraorder ARANEOMORPHAE Smith, 1902
?Superfamily LYCOSOIDEA Homann, 1971

Remarks.—It is impossible to assign the specimen to a family but consideration of its likely mode of life suggests the superfamily Lycosoidea, which includes the Pisauridae, as likely (see Discussion). We do not wish to leave the spider, which is important as the only known Korean fossil spider, nameless, so it is described and named here, and its diagnosis is sufficiently distinctive to allow future conspecifics to be identified.

Genus KOREARACHNE, new genus

Type species.—*Korearachne jinju*, n. sp., by monotypy.

Diagnosis.—Ecribellate entelegyne spider with relatively long, setose walking legs, sparse macrosetae on tibiae and metatarsi of legs 1 and 2; no scopulae.

Etymology.—From Korea, and Greek *arachne*, a spider.

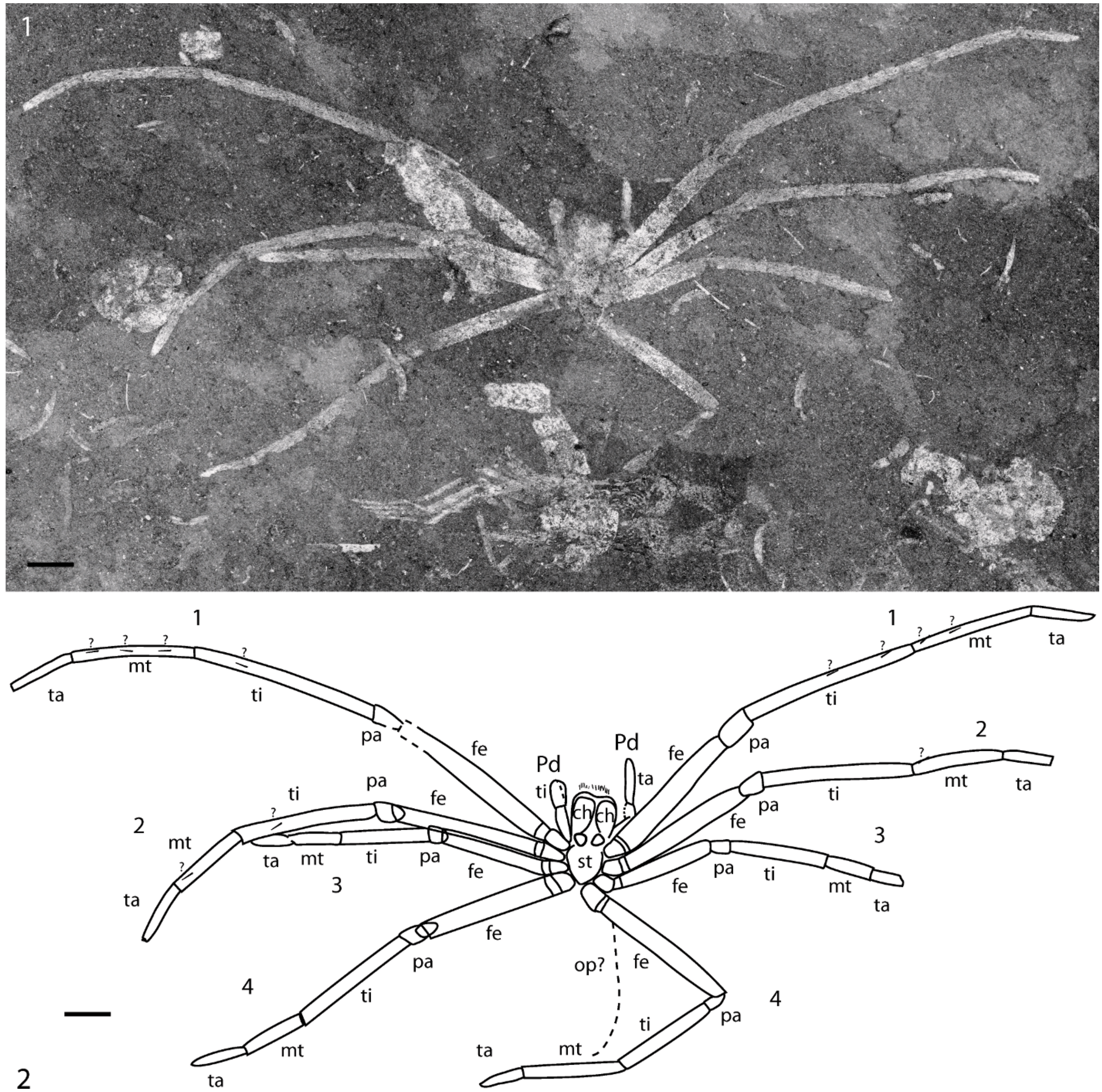

FIGURE 3—*Korearachne jinju* n. gen. n. sp., holotype TSH-0808, Cretaceous of Korea. *1*, photograph of the specimen; *2*, explanatory drawing to accompany *3.1*. Questionable macrosetae marked with ? Scale bars=1.0 mm.

KOREARACHNE JINJU, new species
Figure 3

Pisaura sp. KIM AND NAM 2008, p. 121, fig. 2.

Material examined.—Holotype and only specimen, TSH-0808, in the Natural Heritage Center of Korea, 396-1 Mannyeon-dong Seo-gu, Daejeon, South Korea; from the Jinju Formation (=Dongmyeong Formation) in the Sacheon region (Guho-ri Chookdong-myeon, Sacheon-si, Gyeongsangnam-do).

Etymology.—After the Jinju Formation in which the fossil was found.

Description of TSH-0808.—Female or juvenile. Sternum length 0.88, width 0.89. Maxilla length 0.25. Chelicera length 0.85. Legs and pedipalps with dense setation, few macrosetae (on tibia and metatarsus 1 and 2); tarsi not flexible, no scopulae, no calamistrum; leg formula 1243. Podomere lengths: pedipalp femur 0.78, tibia 0.68, tarsus 1.00; all leg coxae 0.50, all trochanters 0.20; leg 1 femur 3.82, patella 0.80, tibia 4.52, metatarsus 3.03, tarsus 1.60 (total length 14.48); leg 2 femur 3.48, patella 0.67, tibia 3.54, metatarsus 2.10, tarsus 1.40 (total length 11.88); leg 3 femur 2.49, patella 0.51, tibia 2.26, metatarsus 1.36, tarsus 0.92 (total length 8.20); leg 4 femur 3.39, patella 0.60, tibia 2.9, metatarsus 2.01, tarsus 1.25 (total length 10.83).

DISCUSSION

Taphonomy and paleoecology.—Most sedimentological and paleontological evidence points to a lacustrine environment for the Jinju Formation, yet the abundant albuiform fish, at least on the bedding plane bearing the fossil spider, suggests a marine setting. It is possible that there was a connection to the sea at times during the deposition of the Formation, or that albuiforms were non-marine, at least for part of their life cycle, in the Cretaceous. Further discussion is beyond the scope of this paper.

The juxtaposition of so many carcasses on a single bedding plane (Fig. 2) suggests a mass mortality event which killed the fish, ?crustaceans and perhaps also the insects and spider. A variety of causes have been suggested for mass mortality of fish in Cretaceous lakes; for example, Martill et al. (2008) summarized causes for mass mortalities in the Crato Formation of Brazil including: anoxia, dinoflagellate or cyanobacterial blooms, desiccation, water temperature fluctuations, hypersalinity, benthic water overturn, stranding, post-mating/spawning death, earthquakes, and storms. Pan et al. (2011) discussed the causes of mass mortality in the Cretaceous Yixian Formation of China and concluded that periodic volcanic ash falls changed the water quality which caused collapse of the aquatic ecosystem. Few of the causes put forward by Martill et al. (2008) would apply to the death of the Korean spider and insects, so either the cause was a catastrophe such as a storm or volcanic ash fall which would cause mortality of both aquatic and terrestrial biota, or the death of the terrestrial biota was unrelated to the mass mortality in the aquatic ecosystem. There is no evidence for storms or volcanic ash falls in the Jinju Formation, so it is more likely that the terrestrial biota became incorporated with the aquatic organisms randomly. From that point on, the taphonomic process affected all organisms.

One of the problems of preserving insects and spiders in aquatic sediments is that they usually float on the water surface and lack a transport mechanism to the lake floor. However, in some cases, such as the Eocene Florissant deposits of Colorado, microbial activity has been shown to be important in the preservation of the terrestrial and aquatic biota (O'Brien et al., 2008). At Florissant, seasonal diatom blooms may have caused mortality among the aquatic fauna, and formed a mucilaginous mat which then sank to the lake floor, carrying its cargo of dead insects, spiders and leaves from the surface film. O'Brien et al. (2008) postulated a similar taphonomic process for other lacustrine Lagerstätten, and Pan et al. (2011) postulated the possible existence of a microbial mat in the Yixian beds. Such a process may have occurred in the Jinju Formation but has yet to be studied; however, benthic microbial mats have been demonstrated in the Jinju Formation (Paik, 2005), which show evidence of subaerial exposure, although the spider fossil is preserved in a different lithology from that of the microbial-caddis bioherms described by Paik. Nevertheless, another possibility is that the terrestrial biota commingled with the aquatic organisms during a mass mortality event caused by desiccation.

Identification of the spider.—Kim and Nam (2008) placed this fossil spider in *Pisaura* sp. (Pisauridae) without justification. The specimen shows no synapomorphies of the family, let alone the extant genus. Its identity is, nevertheless, problematic. Many spider families can be ruled out but the fossil shows few diagnostic features. The leg formula 1243 is not unusual but the legs are rather long and the sparsity of macrosetae, in particular, is rare in spiders. Most spiders which lack or have sparse leg macrosetae also lack dense setation (e.g., *Trachelas*: Corinnidae; Dondale and Redner, 1982). Leg spines are sparse or lacking in some Dictynidae, but the genera that lack them are small and cribellate (Bennett, 2005), whereas the fossil spider is ecribellate and rather longer-legged. Some desids have reduced leg spination (Forster, 1970), but these spiders have large, porrect chelicerae, which the fossil likely does not. *Loxosceles* (Sicariidae) has few spines and otherwise rather hairy legs, but the chelicerae appear widely separated, which would rule out these and other scytodoids.

The habitus is not unlike that of pisaurids, and it is tempting to look toward families which are typically found in aquatic environments. This could be what led the arachnologist Joo-Pil Kim (Kim and Nam, 2008) to suggest *Pisaura* as the identity of the fossil; similarly, a spider from the Cretaceous of Botswana was placed in the superfamily Lycosoidea (the superfamily to which Pisauridae belongs: Griswold, 1993) solely on habitus and habitat (Rayner and Dippenaar-Schoeman, 1995). Pisaurids have a meager fossil record, being known from Oligocene–Miocene Mexican amber (Petrunkevitch, 1963, 1971), Eocene Baltic amber (Petrunkevitch, 1942, 1958; Wunderlich, 2004), Cretaceous Burmese amber (Penney, 2004), and Eocene lacustrine deposits of British Columbia, Canada (Selden and Penney, 2009). The Mexican amber genus *Propago* Petrunkevitch, 1963 was considered a probable zodariid by Roth (1965).

In conclusion, it is impossible to assign the fossil spider to a particular family, but some suggestions can be made regarding its possible identity and mode of life. The habitus suggests neither that of an aerial web dweller nor a ground spider. The lack of scopulae or claw tufts rules out a fast-running spider of tree trunks or hard substrates; the legs do not appear laterigrade nor bear long spines which would be appropriate for a sit-and-wait predator; while leg lengths and setation suggest possibly a wanderer on soft substrates. So the likelihood is that the spider lies among the lycosoids. With continued collecting at localities in the Jinju Formation, it is to be hoped that further specimens will turn up, with better preservation, which will help to further characterize this enigmatic fossil.

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