NEW EOCENE HYDROCARBON SEEP DECAPOD CRUSTACEAN (ANOMURA: GALATHEIDAE: SHINKAIINAE) AND ITS PALEOBIOLOGY

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ABSTRACT—A new decapod crustacean species, *Shinkaia katapsyxis*, is reported from the Eocene Humptulips Formation of western Washington, USA. The specimens were collected from a hydrocarbon seep deposit that has been well-documented and contains a well-described molluscan fauna. The new occurrence extends the geologic range of the genus *Shinkaia* Baba and Williams, 1998, and subfamily Shinkaiinae Baba and Williams, 1998, into the Eocene from its only other known occurrences in hydrothermal vent environments in the Pacific Ocean. The range extension of an extant decapod genus into the Eocene is not uncommon and adds to the evidence that the Decapoda may be unusually resistant to extinctions and are distinctly conservative evolutionarily.

INTRODUCTION

DECAPOD CRUSTACEANS from fossil hydrocarbon seep and hydrothermal vent environments are poorly known. Until now, only four other named and described fossil decapod species were known worldwide from such environments (Bishop and Williams, 2000). The ichnogenus *Palaxius* Brönniman and Norton, 1960, fecal pellets attributed to a decapod, has been reported from such environments (Peckmann et al., 2007). Herein we report a new species of the sole genus in the galatheid subfamily Shinkaiinae Baba and Williams, 1998, which is also the first occurrence of the subfamily and the genus in the fossil record.

GEOLOGIC SETTING

Overview.—The Paleogene hydrocarbon seep environments (sometimes called methane seeps or cold seeps) of the Pacific Northwest of North America have been well-summarized over the past two decades. Goedert and Squires (1990) provided an overview of several Eocene seep localities, including the Humptulips Formation site detailed herein. Seep deposits are well known from the Paleogene of the region, and they are well documented in modern oceans of the area (Sibuet and Olu, 1998). Campbell (2006) summarized the paleontological aspects of seeps and hydrothermal vents over the entire geologic time scale.

Terminology.—There is some inconsistency in usage in the geological literature of the terms cold seep, methane seep, and hydrocarbon seep, and there is also inconsistency in the application of the terms hydrothermal vent and hydrocarbon seep (see also discussion in Campbell, 2006). The same formation may be referred to by one term in one series of papers, and by another term in other papers (see discussion of Tepee Buttes below for a good example). The three terms, hydrocarbon seep, cold seep, and methane seep, seem to refer to an environment in which hydrocarbons are released into an oceanic environment at a "low" temperature that is similar to that of the environment (see Campbell, 2006, for a more complete discussion). Sibuet and Olu (1998) suggested temperatures in cold seep environments of about 0.5°C. We will use the term "hydrocarbon seep" or just "seep," as the latter does not imply a specific temperature or molecule that is being released.

This type of environment is generally considered to be distinct from hydrothermal vent environments, although the two environments are very similar and their separation is perhaps artificial (Van Dover et al., 2002). Hydrothermal vent environments are characterized by hot water being ejected into a typically deep ocean environment; the water is geothermally heated and is enriched in various chemicals that make possible chemoautotrophic life (Van Dover, 2000; Van Dover et al., 2002). Temperatures for the water emanating from these vents in which animals are living, as reported from the literature, ranged from 25°C (Van Dover, 2000, p. 92) to upwards of 105°C (Van Dover, 2000, p. 202).

Campbell (2006, p. 383) gave ranges of temperatures from 40–90°C as "warm" and those of less than 60°C as "low." Thus, temperature regime and its interpretation seem to be quite variable.

Hydrothermal vent and hydrocarbon seep environments appear to be similar in that both are based upon chemosynthetic producers and sulfur and/or methane chemicals (Chevaldonné and Olu, 1996; Van Dover et al., 2002; Campbell, 2006; Krylova and Sahling, 2006). Thus, it is not unusual for taxa to be present at both hydrothermal vent and hydrocarbon seep environments (Van Dover, 2000); in fact, many summaries include both environments when providing faunal lists (Chevaldonné and Olu, 1996; Martin and Haney, 2005; Campbell, 2006, for example). Sibuet and Olu (1998) provided a detailed comparison of vent and seep environments and similarly found that taxa within the same family and genus were often found at both vent and seep environments, although the species differed. Thus, it seems that water chemistry and not water temperature is the common factor in the two environments. Temperature may not be a major factor.

Humptulips Formation.—The Humptulips Formation is composed of about 1,000 m of siltstone and mudstone cropping out in west-coastal Washington state (Rau, 1984). Recent work on magnetostratigraphy and foraminiferans has constrained its age at earliest middle Eocene (Prothero et al., 2001). The fossils described herein were collected from an isolated outcrop of limestone within the unit, interpreted as having been precipitated as a result of the hydrocarbon seep environment. Studies have shown that carbonates can be precipitated due to the presence of certain bacteria in these environments (Campbell, 2006). Specimens were collected from LACM 12385, "an abandoned meander on the East Fork of the Humptulips River in the northwest part of sec. 4, T20N, R9W, Quinault Lake 15-minute quadrangle, Grays Harbor County" (Goedert and Squires, 1990, p. 1182).

Fossils previously described from the unit include serpulid worm tubes, gastropods, pelecypods, polyplacophorans, and crustacean ichnofossils (Goedert and Squires, 1990; Squires and Goedert, 1991, 1995; Goedert and Kaler, 1996; Kiel, 2006; Peckmann et al., 2007). Many of the molluscan reports have extended the geologic range of the relevant taxa, not unlike the range extension for the galatheid decapod crustacean reported below.

Other fossil seep/vent Decapoda.—The geologic record of the Decapoda specifically in seep and vent environments was recently summarized by Peckmann et al. (2007). Campbell (2006) listed published localities where decapod fossils had been found; most of these simply refer to crustaceans (i.e., Peckmann et al., 1999) or decapods (i.e., Collins, 1999).

The only other North American occurrence of named decapods from a hydrocarbon seep or hydrothermal vent to which the new decapods might be related is from the Tepee Buttes (sometimes spelled Teepee). This unit is a well-known Late Cretaceous seep

deposit (Kauffman et al., 1996) within shales of the Western Interior of North America. Bishop and Williams (2000), who described four species of Brachyura from the unit, suggested that it might in fact be a warm-water seep. They did not suggest a temperature range for what might constitute "warm water;" we hypothesize that they may have meant an environment more similar to a hydrothermal vent rather than to a hydrocarbon seep.

The terminology used for the Tepee Buttes deposits has been variable and confusing. Kauffman et al. (1996) presented a temperature range of 15–25°C for the Tepee Butte depositional environment but noted that their carbon isotope results were consistent with those seen at modern-day hydrocarbon seeps. Kauffman et al. (1996, p. 799) referred to the Tepee Butte environment as an area in which "methane-rich fluids" were vented from springs. Some later work has interpreted the Tepee Buttes as a cold seep deposit (Powell et al., 1998; Metz, 2002; Dahl et al., 2005); others described it as a methane or hydrocarbon seep (Shapiro and Gale, 2001; Shapiro and Fricke, 2003; Shapiro, 2004; Anderson et al., 2005; Morgan et al., 2005; Close and Parsons-Hubbard, 2006; Campbell, 2006). Based upon a detailed discussion of the nomenclature surrounding hydrothermal vents and hydrocarbon seeps (Campbell, 2006), it seems that the Tepee Buttes were most likely a hydrocarbon seep environment, typical of those of today. There seems to be no evidence that there was hydrothermal activity.

Significantly and not noted by the original authors, the decapods described from the Tepee Buttes are members of families not known from either seep or hydrothermal deposits. These families and some of the genera have, however, been previously reported from other localities in the Pierre Shale, the unit that encloses many of the Tepee Butte structures (Bishop, 1981, 1982, 1986, 1988, 1992). Two of the taxa are members of the Raninidae de Haan, 1839, which have not been reported thus far from seeps or vents in modern oceans (Martin and Haney, 2005). A third taxon is a member of an extinct genus, *Plagiophthalmus* Bell, 1863, whose most closely related extant family would likely be the Dynomenidae Ortmann, 1892; Dromiidae de Haan, 1833; or Homolodromiidae Alcock, 1900; none of which is found in seep or vent faunas today (Martin and Haney, 2005). The third, poorly preserved specimen is possibly a member of the Homolidae de Haan, 1839, which is represented in modern hydrothermal vent faunas (Martin and Haney, 2005) but is not restricted to hydrothermal areas. Regardless of whether the Tepee Butte environment was a hydrothermal vent or a hydrocarbon seep, it clearly supported a different decapod fauna than do these types of environments in modern oceans, even though many of the decapod families known today from such environments were already present by Cretaceous time (Glaessner, 1969; Martin and Haney, 2005). The relatively shallow depth of formation of the Tepee Buttes and their location on a continental shelf instead of in an oceanic environment may account for these faunal differences. It is possible that the Tepee Butte environment was colonized by organisms living in the neighboring deep-water Pierre Shale depositional environment.

SYSTEMATIC PALEONTOLOGY

Order DECAPODA Latreille, 1802
Infraorder ANOMURA MacLeay, 1838
Superfamily GALATHEOIDEA Samouelle, 1819
Family GALATHEIDAE Samouelle, 1819
Subfamily SHINKAIINAE Baba and Williams, 1998
Genus SHINKAIA Baba and Williams, 1998

Type species.—*Shinkaia crosnieri* Baba and Williams, 1998.
Included species.—*Shinkaia crosnieri* (Recent); *S. katapsyxis* new species.
Diagnosis.—Carapace ovate, longer than wide; rostrum flat, spatulate, with or without lateral spines; two antennal (of Baba

and Williams, 1998; =anterolateral spine of McLaughlin, 1980) spines; weak, simple, nearly straight cervical groove; with or without tiny spines along entire lateral margins of carapace; simple carapace ornamentation consisting of small scabrous ridges; deep pit on inner surface of fixed finger of cheliped; long spines on upper surface of carpus of cheliped; eyes reduced.
Material examined.—Holotype, USNM 251480; paratype USNM 251481.
Discussion.—Baba and Williams (1998) described the new genus *Shinkaia* and subfamily Shinkaiinae for galatheid specimens collected from hydrothermal vent communities in the North Pacific near Japan and Papua New Guinea. Subsequently, Chan et al. (2000) reported the same species from hydrothermal environments of Taiwan. Thus far, this genus is the only member of the subfamily.

The new fossil specimens attributed to *Shinkaia* are remarkably similar to the type species, especially given the approximately 40 million year age difference between them. The fossils possess all of the diagnostic features of the genus. The extant species was described as being covered with setal hairs, especially on the ventral surface (Fig. 1.3, 1.4). The ventral surface is not preserved in the fossils, and only one incomplete abdomen is present (Fig. 2.1, 2.2); however, we note the presence of setal pits on many of the carapace surfaces on the fossil specimens.

The recent *Shinkaia crosnieri* was described as having small spines on the lateral margins of the rostrum (Fig. 1.1); however, Baba and Williams (1998) noted that spines of the carapace could become worn away over time as did Chan et al. (2000), whose specimens lacked the lateral spines described for the type material of *S. crosnieri*. The new fossils lack spines on the rostrum (Fig. 2.1–2.3, 2.6, 2.7). *Shinkaia crosnieri* narrows considerably posteriorly and much more so than the new fossils described herein (Figs. 1.1–1.2, 2). In addition, the new fossils do not share the spines on the outer surface of the manus with *S. crosnieri* (Figs. 1.1–1.2, 3). We regard these as species-level differences.

The pits on the inner surface of the fixed finger in the extant and fossil species are variable in size. In the male holotype specimen of *S. crosnieri* (Fig. 1.4) and in an ovigerous female, the pits are large and deep. In a non-ovigerous paratype female of *S. crosnieri* (Fig. 1.3), the pits are quite small and shallow. Fossil specimens not associated with dorsal carapaces similarly show a range in pit size (Fig. 3.2–3.4, 3.6, 3.8). Thus, the variability in pit size is seen in both the extant and fossil species.

SHINKAIA KATAPSYXIS new species
Figures 2, 3

Diagnosis.—Carapace ovate, widest about three-quarters the distance posteriorly; rostrum flat, spatulate, without small spines on lateral margins; two antennal (=anterolateral) spines; cervical groove weak, simple, nearly straight; lateral margin of carapace with tiny spines; simple carapace ornamentation consisting of small scabrous ridges; deep pit on the inner surface of the fixed finger of the cheliped; long spines on the upper surface of carpus of cheliped; cheliped heavily ornamented with scabrous ridges on outer surface, long spines on upper and lower surfaces.
Description.—Carapace longitudinally ovate, longer than wide, width about two-thirds maximum length, widest about three-quarters the distance posteriorly on carapace; moderately vaulted transversely and longitudinally; overall weakly ornamented.

Rostrum long, about one-quarter maximum carapace length, proportionally longer in smaller specimens, flattened, blunt tipped, narrowed slightly at base but otherwise parallel-sided, margins entire. Anterior margin of carapace smoothly concave on either side of rostrum. Antennal spines situated on either side of rostrum but at some distance from it, width between spines 55% maximum carapace width; spines broadly triangular, concave on inner upper surface. Anterior margin sloping weakly posteriorly distal to spines, with weak flattened area distal to spine.

Lateral margins convex, ornamented with about 25 tiny, needlelike spines; spines weakening into tiny bumps posteriorly. Posterior margin broad, nearly straight, weakly rimmed.

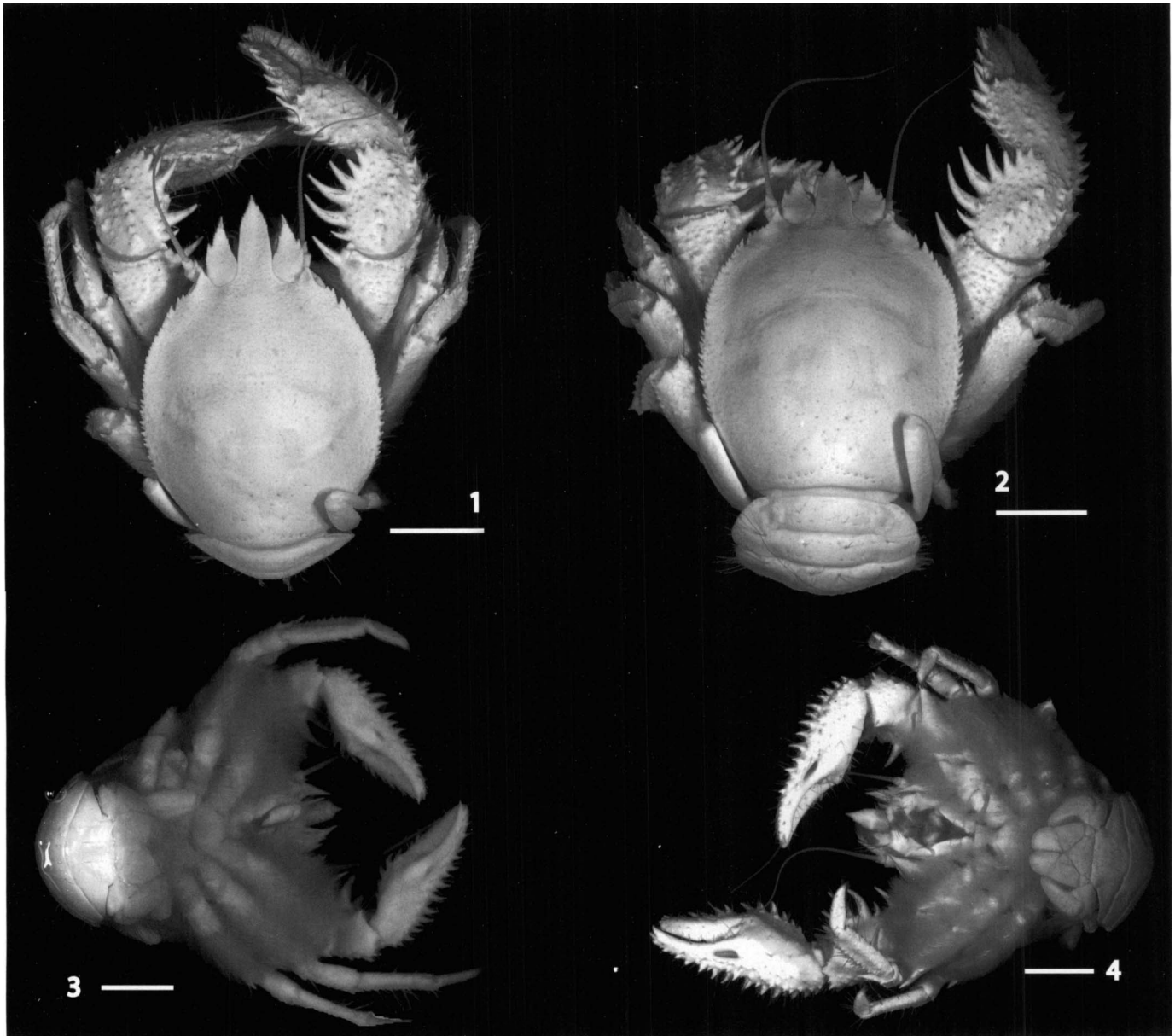Dorsal carapace appearing smooth anteriorly; under 25× magnification,

FIGURE *1*—*Shinkaia crosnieri* Baba and Williams, 1998. *1, 2, 4*, USNM 251480, holotype, male, 4 shows large pits on inner surface of fixed finger; *3*, USNM 251481, paratype, non-ovigerous female showing small pits on inner surface if fixed finger. Scale bars = 1 cm.

tiny, scabrous ridges visible which may have supported setae. Weak cervical groove located about 55% the distance posteriorly measured along axis and including rostrum; composed of central, weakly convex forward segment and two nearly straight lateral segments. Carapace immediately posterior to groove with tiny scabrous ridges; posteriorly, ridges becoming larger, transverse, and more pronounced laterally. Cardiac region transversely ovate and raised slightly more than other carapace regions. Intestinal region broadly triangular, weakly inflated, smooth.

Abdominal somite 1 wider than long, not as wide as other somites. Abdominal somites 2 and 3 much wider than long. Somite 4 ovate, longest axially, with rim on proximal margin. Somite 5 wider than long. Somite 6 widest axially, becoming narrower and tapering distally along margins to accommodate triangular uropods. Telson poorly known. Gender of specimen with abdomen unknown.

Carpus of major cheliped short, about as long as high, becoming higher distally; proximal margin rounded; lower margin sloping obliquely distally; upper margin with five very long, forward-arcing spines; distal margin sinuous; outer surface ornamented with longitudinal, scabrous ridges with forward-directed setal pits.

Manus of major cheliped stout, becoming higher distally; proximal margin rounded, short; upper margin oblique, with several short, forward-directed spines; lower margin weakly convex, with several short spines; outer surface

of manus with longitudinal, short, scabrous ridges with forward-directed setal pits. Fixed finger stout, very high proximally, narrowing somewhat distally; lower margin with distally curved spines; with low, blunt teeth on occlusal surface, appearing to have had dense cuticle at tip. Movable finger also stout, upper margin with short spines, tip of occlusal surface with thickened cuticle. Inner surface of fixed finger with deep, longitudinally ovate pit; pit variable in size, not extending through finger.

Measurements.—Measurements (in mm) taken on specimens of *Shinkaia katapsyxis* new species are presented in Table 1.

Etymology.—The trivial name is the feminine Greek word *katapsyxis*, meaning chill, in reference to the association of the new species with hydrocarbon seeps, often referred to as cold seeps, whereas the modern species is known from hydrothermal areas.

Types.—The holotype, USNM 536286, and 19 paratypes, USNM 536287–536305 are deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C. Seven paratypes, UWBM 98522–98528 are deposited in the Burke Museum of Natural History and Culture, University of Washington, Seattle, Washington.

Occurrence.—The specimens were collected from the Humptulips Formation discussed above.
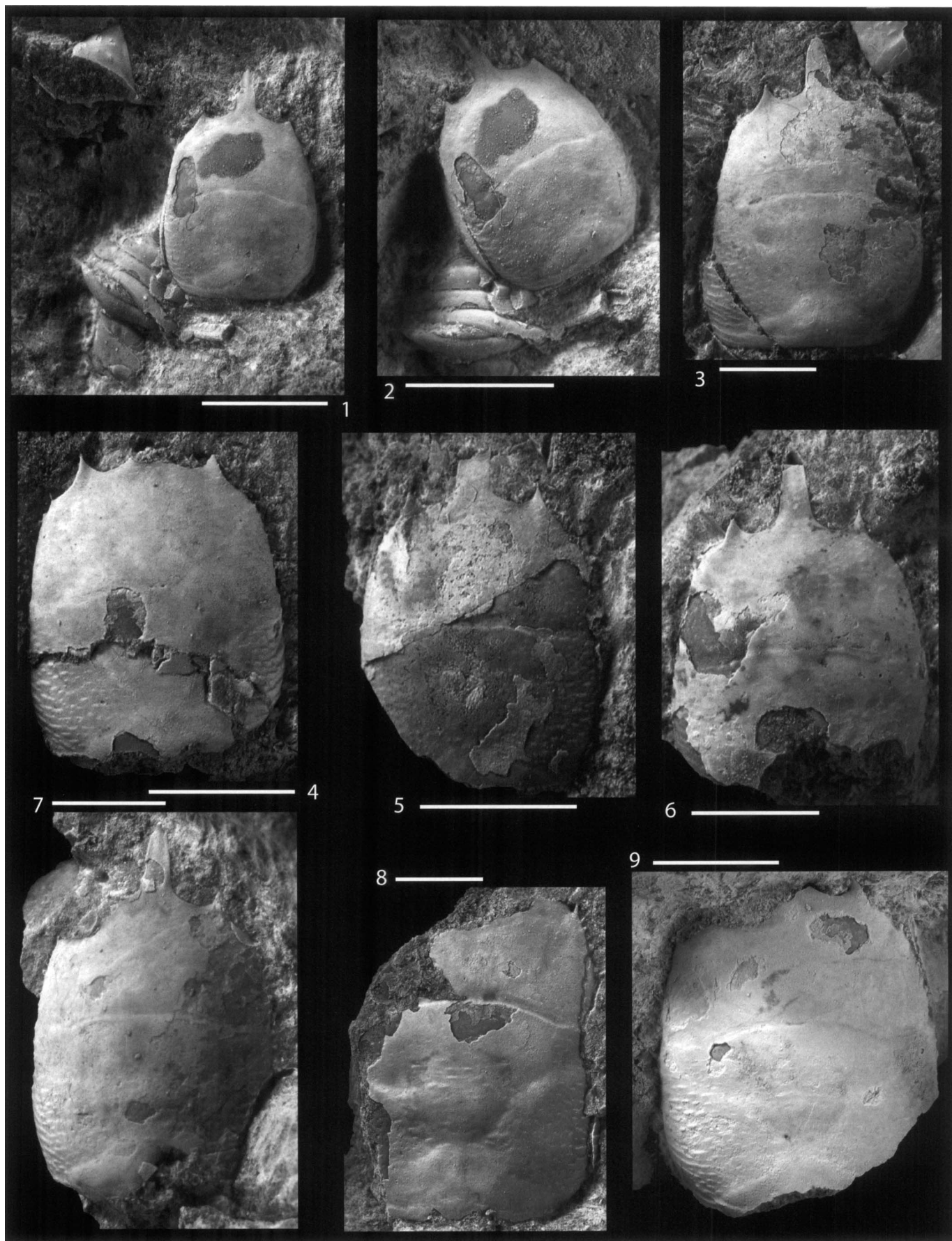
PALEOBIOLOGY

Paleoecology.—The discovery of members of the Galatheidae in rocks of the Humptulips Formation, a hydrocarbon seep deposit, is not surprising. It has been well documented that in modern oceans, galatheids are commonly found in hydrocarbon seep and hydrothermal vent environments (Tunnicliffe, 1992; Chevaldonné and Olu, 1996; Sibuet and Olu, 1998; Martin and Haney, 2005; Campbell, 2006). Many published images show galatheids swarming in large numbers at such localities (Chevaldonné and Olu, 1996, fig. 1; Baba and Williams, 1998, fig. 3). The illustration of Baba and Williams specifically shows *Shinkaia crosnieri*. Ohta and Kim (2001) reported swarms of *Shinkaia* at hydrothermal sites.

In the specimens under study herein, 112 dorsal carapaces, 107 pairs of claws, and dozens of fragments of pereiopods of *Shinkaia katapsyxis* were counted in just over 22 kg of rock. Although it is true that the specimens sent to us for study were those that preferentially contained decapod crustacean fragments, most of the rock was in the form of large, bulk samples (Fig. 4). To put the number of decapod specimens in perspective, the same bulk rock specimens contained 60 pelecypods, 52 individual worm tubes and four worm tube clusters, 53 coiled gastropods, and 30 limpets. These specimens are of the same type illustrated by Goedert and Squires (1990, fig. 2b, 2d, 2f, 2g, 2i, 2j, 2n, 2t), with the exception of large, black tubes we interpreted as worm tubes but that are different than those illustrated by Goedert and Squires (1990, fig. 2i). This is a large number of decapod crustaceans in comparison with the usually much more commonly preserved molluscan fauna. This suggests that *Shinkaia katapsyxis* exhibited a similar lifestyle to its modern congener, living gregariously in swarms with large numbers of individuals of its own species. In many of the specimens interpreted to exhibit worm tube clusters, the worm tubes are intermingled with pereiopod fragments of *S. katapsyxis* so that it is at times difficult to determine whether the circular cross-sections are through worm tubes or pereiopods. This suggests that *S. katapsyxis* lived among worm tube clusters, perhaps for protection because it would be camouflaged (at least from predators using tactile means, as the worm tubes and pereiopods are about the same diameter) among the tubes.

Within the Galatheidae and the closely related Chirostylidae Ortmann, 1892b, species of the same genus are known from hydrocarbon seep sites and from ridges and chimneys, which are hydrothermal sites (Martin and Haney, 2005, table 1). Chevaldonné and Olu (1996) and Sibuet and Olu (1998) reported different species of the same genus of galatheid from both vents and seeps. Thus, report of different species of the same genus of galatheid from both hydrothermal and hydrocarbon seep localities is not unusual, and is in fact, well documented.

Shinkaia appears to be uniquely adapted to the seep/vent habitat. The adult extant specimens have reduced eyes (Baba and Williams, 1998) or no eyes, according to Miyake et al. (2007), an adaptation to low light levels. However, the larval forms do indeed have eyes (Miyake et al., 2007), suggesting that *Shinkaia* may be a descendent of organisms inhabiting shallower-water, photic areas. Alternatively, eyes may be a useful adaptation for the larvae in their buoyant phase, which could include time in the euphotic or dysphotic zones. Too little is known about the larval ecology of *Shinkaia* to test the latter hypothesis. The extant specimens display large numbers of setae (Baba and Williams, 1998),

and the fossil specimens exhibit numerous setal pits. The setae have been reported to support chemosynthetic bacteria (Martin and Helaney, 2005), and Miyake et al. (2007) reported that individuals of *Shinkaia crosnieri* were observed to eat the bacteria. Baba and Williams (1998) noted that the deep pit on the inner surface of the finger of *Shinkaia* was a feature only seen in decapods known from hydrothermal areas; however, its function is unknown.

Paleobiogeography.—The extant species of *Shinkaia* inhabits the Western Pacific, in localities near Japan, Papua New Guinea, and Taiwan (Baba and Williams, 1998; Chan et al., 2000; Martin and Haney, 2005), whereas the new species is located in the northeastern Pacific Ocean. Tunnicliffe and Fowler (1996) and later Van Dover et al. (2002) suggested that the areas of Japan and the northeastern Pacific were not especially closely related biogeographically when only vent faunas were analyzed; however, hydrocarbon seep faunas were not part of that analysis. We suggest that *Shinkaia* could easily have dispersed along subduction zones and ridges in the Northern Pacific, along North America, the Aleutian Islands, and Coastal Siberia and Japan into the regions in which it currently is found. A map plotting known hydrocarbon seep environments in modern oceans shows that they are not widely distributed but are particularly well-represented on the North Pacific rim (Sibuet and Olu, 1998, fig. 1; Campbell, 2006, fig. 1). Thus, organisms adapted to such an environment might be predicted to disperse along these routes. Indeed, Krylova and Sahling (2006) proposed this exact dispersal route for the molluscan genus *Calyptogena* Dall, 1891, which inhabits the entire North Pacific continental marginal area today, has been known from the area since the Miocene, and appears best adapted to hydrocarbon seep conditions. Thus, it seems that hydrocarbon seep biogeographic patterns may indeed be somewhat different and controlled by different factors than those for organisms living strictly or preferentially in hydrothermal vent areas.

Evolutionary dynamics.—Evolutionary dynamics at hydrothermal vents and hydrocarbon seeps have been extensively treated. There are two competing hypotheses with respect to antiquity of faunas at hydrothermal vents, one being that the fauna there consists of relict taxa (MacLean, 1985; Newman, 1985) and the other that the unique conditions at the vents are conducive to rapid evolution, yielding new, younger radiations (Hickman, 1984) (summarized by Van Dover, 2000). Hydrocarbon seeps were not embraced by these hypotheses, although these same hypotheses have been extended to these environments (Van Dover, 2000, p. 325). An additional hypothesis regarding faunas of hydrothermal vent and hydrocarbon seep environments, suggests that some taxa originated in hydrocarbon seep environments and later radiated into hydrothermal vent areas (Van Dover et al., 2002). There is also indication that, at least for mollusks, hydrocarbon seep faunas specifically are older than the marine mollusk fauna overall. This may be because the deep-sea fauna in general displays long generic ranges so that the phenomenon may not be specific to vents and seeps (Kiel and Little, 2006). Because so little is known about cold-seep decapod faunas in the fossil record, it is difficult to test these hypotheses. However, *Shinkaia* is first known from a hydrocarbon seep during the Eocene, and its recent occurrences are from hydrothermal areas, suggesting a move from seeps to vents for this genus.

Resistance to extinction.—Seep and vent faunas appear to be

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FIGURE 2—*Shinkaia katapsyxis* new species, dorsal carapace and abdomen. *1*, USNM 536286, holotype, dorsal carapace and abdominal somites 1–6, *2*, USNM 536286, holotype, oblique view of dorsal carapace and view of abdominal somites 1–4; *3*, USNM 536287, paratype, dorsal carapace; *4*, USNM 536288, dorsal carapace with excellent posterior ornamentation; *5*, USNM 536289, paratype, dorsal carapace showing cervical groove in decorticated area; *6*, USNM 536290, paratype, dorsal carapace showing flattened rostrum; *7*, USNM 536291, paratype, dorsal carapace; *8*, USNM 536292, paratype, incomplete dorsal carapace with well-developed regions; *9*, USNM 536293, paratype, incomplete dorsal carapace with excellent posterior ornamentation. Scale bars = 0.5 cm.
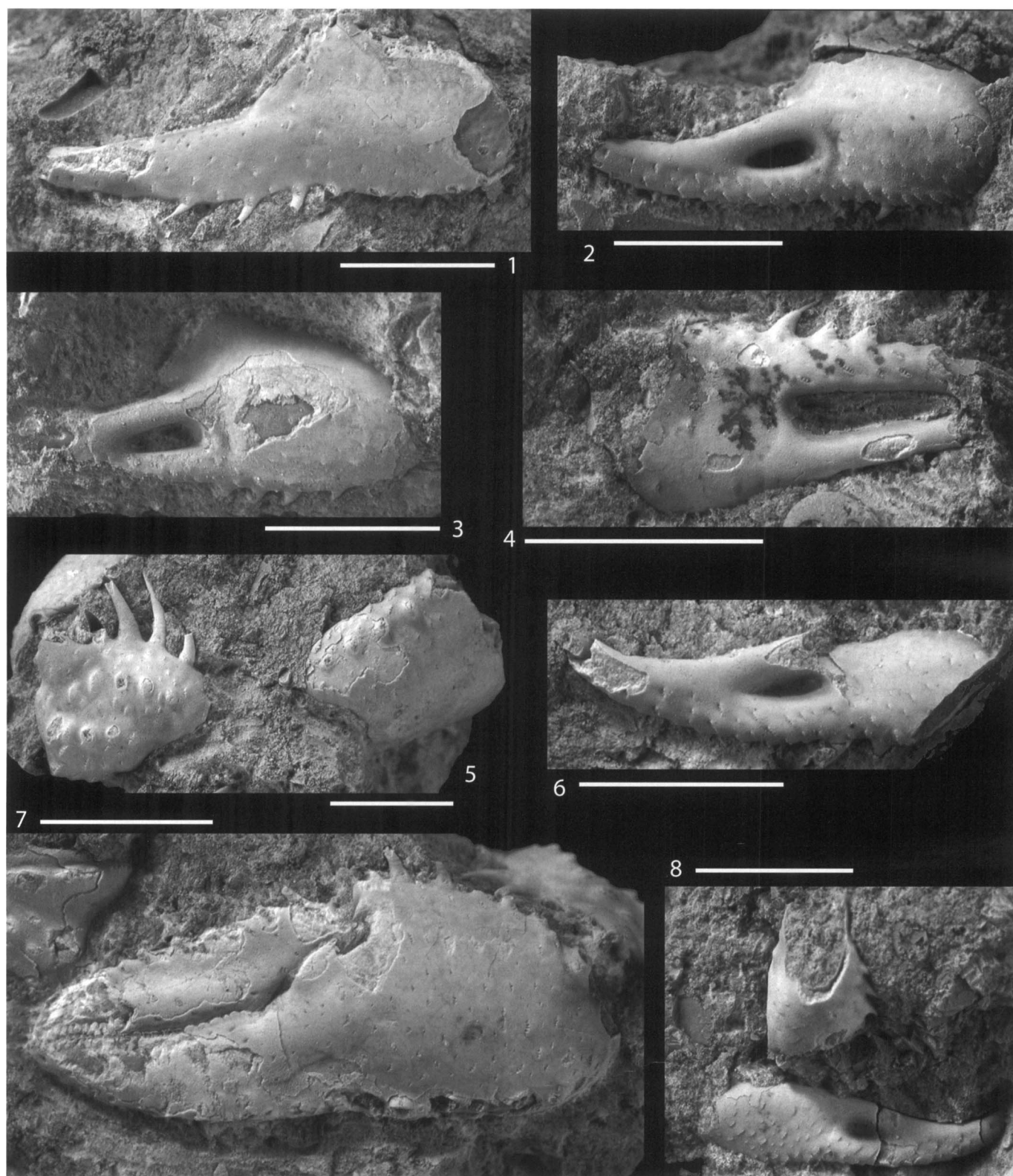
FIGURE 3—*Shinkaia katapsyxis* new species, cheliped elements. *1*, USNM 536294, paratype, outer surface of left chela with fixed finger and large spines on lower margin on fixed finger; *2*, USNM 536295, paratype, inner surface of right chela and fixed finger showing large, ovate cavity; *3*, USNM 536296, paratype, inner surface of right chela and fixed finger with ovate cavity; *4*, USNM 536297, paratype, inner surface of right chela and fixed finger with very elongate cavity; *5*, USNM 536298, paratype, outer surface of carpus of left cheliped, note very long spines on upper surface; *6*, USNM 536299, paratype, inner surface of right fixed finger with small ovate cavity; *7*, USNM 536298, paratype, outer surface of left chela and fingers; *8*, USNM 536300, paratype, inner surface of left fixed finger with small ovate cavity. Scale bars = 0.5 cm.

TABLE *1*—Measurements (in mm) taken on the dorsal carapace of *Shinkaia katapsyxis* new species. L1 = maximum carapace length including rostrum; L2 = length to cervical groove including rostrum; L3 = length of rostrum; W1 = maximum carapace width; W2 = width between antennal spines.

Specimen Number	L1	W1	L2	W2	L3
USNM 536286 (Holotype)	9.2	6.2	5.5	3.6	2.5
USNM 536287	15.7	10.5	8.3	5.8	2.8
USNM 536291	16.4	11.0	8.5	6.0	3.3
USNM 536288	>11.0	9.0	—	4.7	—
USNM 536292	>19.0	—	—	—	—
USNM 536290	>13.5	9.9	8.1	4.9	—

resistant to extinction. The depth of these communities and their dependence on chemosynthesis rather than photosynthesis makes them a natural contender as refugia from impact events or volcanic eruptions clouding the sky with debris and blocking the sun for long time periods (Van Dover, 2000; Van Dover et al., 2002; Kiel and Little, 2006). The hypothesis of offshore transitions of taxa into deeper water presumably to escape predation and competition is well known and tested (Jablonski et al., 1983; Van Dover, 2000).

However, whether *Shinkaia* is a long-lived taxon due to its presence at seeps/vents or due to its taxonomic status is a complex question to unravel. The extension of an extant decapod genus into the Eocene is not unusual. Many extant galatheid genera are already known from the Eocene and even the Cretaceous (Schweitzer and Feldmann, 2000, 2005). Many genera within the less derived brachyuran families, such as the Homolidae and the Raninidae, have confirmed fossil records extending into the Cretaceous (Schweitzer et al., 2004; Feldmann and Schweitzer, 2006). A large number of extant families have Eocene records (i.e., Karasawa and Schweitzer, 2006; Karasawa et al., 2008). The decapods have a documented record of being less impacted by the end-Cretaceous mass extinction event, at the family level, than many other groups (Schweitzer and Feldmann, 2005). Long lived lineages are common; therefore, the long geologic range of the Galatheidae in hydrocarbon seeps may be more a function of the evolutionary patterns of the Decapoda than of factors inherent in the environment. Decapods appear to be either resistant to extinction or evolutionarily conservative, or both.

Shinkaia inhabited an environment different from that for other previously reported Paleogene decapod crustaceans, but its geologic longevity and evolutionary conservatism are similar to those
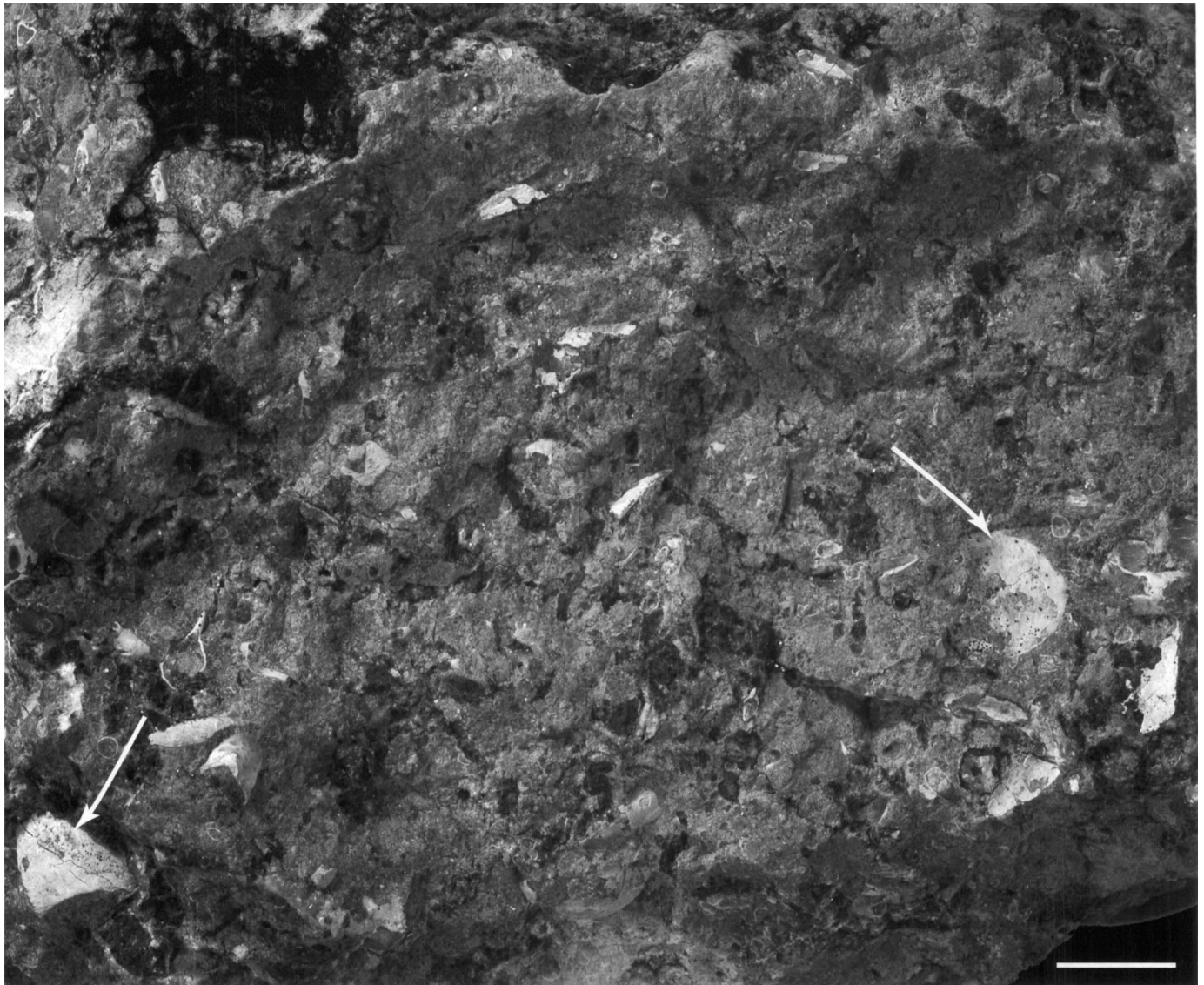

FIGURE *4*—Bulk rock sample, UWBM 98522, showing abundance of fragments of *Shinkaia katapsyxis* in sediment. Arrows indicate dorsal carapace fragments; other white fragments are portions of chelae and pereiopods. Scale bar = 1 cm.

for other decapods. Whether this is coincidental or a feature of the Decapoda themselves remains to be tested. In addition, Kiel and Little (2006) noted that vent and seep faunas tended to be comprised of both ecological generalists and specialists and suggested that the apparent resistance of vent/seep faunas to extinction was potentially a complicated pattern. We suggest here that not only is resistance and/or propensity for extinction dependent upon a variety of factors that may be contingent upon physical environment, they are also dependent upon the taxon in question. The Decapoda have a history of evolution and extinction that differs from that of other organisms. Thus, generalities made about the end-Cretaceous and other mass extinctions based upon mollusks, microfossils, and certain vertebrates are inappropriate when applied to the Decapoda and are not necessarily applicable to all other groups of organisms. In addition, the question of antiquity of lineages within the vent/seep environment is complicated and may be dependent upon the vent/seep environment, the overall depth, the taxon involved, or some combination thereof.

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