FISHES OF THE MIO-PLIOCENE WESTERN SNAKE RIVER PLAIN AND VICINITY

IV. FOSSIL FISHES FROM THE MIOCENE ELLENSBURG FORMATION, SOUTH CENTRAL WASHINGTON

by

GERALD R. SMITH, JAMES E. MARTIN, NATHAN E. CARPENTER

MUSEUM OF ZOOLOGY, UNIVERSITY OF MICHIGAN, 204 no. 4

The publications of the Museum of Zoology, The University of Michigan, consist primarily of two series—the *Miscellaneous Publications* and the *Occasional Papers*. Both series were founded by Dr. Bryant Walker, Mr. Bradshaw H. Swales, and Dr. W. W. Newcomb. Occasionally the Museum publishes contributions outside of these series. Beginning in 1990 these are titled *Special Publications* and *Circulars* and each are sequentially numbered. All submitted manuscripts to any of the Museum's publications receive external peer review.

The *Occasional Papers*, begun in 1913, serve as a medium for original studies based principally upon the collections in the Museum. They are issued separately. When a sufficient number of pages has been printed to make a volume, a title page, table of contents, and an index are supplied to libraries and individuals on the mailing list for the series.

The *Miscellaneous Publications*, initiated in 1916, include monographic studies, papers on field and museum techniques, and other contributions not within the scope of the *Occasional Papers*, and are published separately. Each number has a title page and, when necessary, a table of contents.

A complete list of publications on Mammals, Birds, Reptiles and Amphibians, Fishes, Insects, Mollusks, and other topics is available. Address inquiries to Publications, Museum of Zoology, The University of Michigan, Ann Arbor, Michigan 48109–1079.

RECENT *MISCELLANEOUS PUBLICATIONS*

Smith, G. R., Zaroban, D. W., High, B., Sigler, J. W., Schilling, J., Krabbenhoft, T. J. and Dowling, T. J. 2018. Introgressive mtDNA Transfer in Hybrid Lake Suckers (Teleostei, Catostomidae) In Western United States. pp. 87-118, figs. 14, 7 tables. *In*: Fishes of the Mio-Pliocene Western Snake River Plain and Vicinity. *Misc. Publ. Mus. Zool., Univ. Michigan*, No. 204, no. 3.

Smith, G. R., Chow, J., Unmack, P.J., Markle, D.F. and Dowling, T.E. 2017. Evolution of the Rhinicthys Osculus Complex (Teleostei: Cyprinidae) in Western North America. pp. *i-vi*, 44-83, figs. 17, 4 tables, 1 appendice. *In*: Fishes of the Mio-Pliocene Western Snake River Plain and Vicinity. *Misc. Publ. Mus. Zool., Univ. Michigan*, No. 204, no. 2.

Stearley, R. F. and G. R. Smith, 2016. Salmonid fishes from Mio-Pliocene lake sediments in the Western Snake River Plain and the Great Basin. pp. 1-43, 17 figs., 4 tables, 3 maps. *In*: Fishes of the Mio-Pliocene Western Snake River Plain and Vicinity. *Misc. Publ. Mus. Zool., Univ. Michigan*, No. 204.

Cohn, T. J., D. R. Swanson, P. Fontana. 2013. Dichopetala and New Related North American Genera: A Study in Genitalic Similarity in sympatry and Genitalic Differences in Allopatry (Tettigoniidae: Phaneropterinae: Odonturini). *Misc. Publ. Mus. Zool., Univ. Michigan*, No. 203, pp. *i-vi*, 1-175, 11 maps, 5 tables, 5 appendices.

Talbot, M. 2012. The natural history of the ants of Michigan's E. S. George Reserve: A 26 year study. *Misc. Publ. Mus. Zool., Univ. Michigan*, No. 202, pp. *i-v*, 1-219, 161 maps, 7 tables, 2 appendices.

RECENT *OCCASIONAL PAPERS*

Kraus, Fred. 2015. A new species of the miniaturized frog genus *Paedophryne* (Anura: Microhylidae) from Papua New Guinea. *Occ. Pap. Mus. Zool., Univ. Michigan,* No. 745, pp. 1-11, 2 figs., 1 table, 1 map.

Wilkinson, M., A. O'Connor, R.A. Nussbaum. 2013. Taxonomic status of the neotropical Caeciliam genera *Brasilotyphlus* Taylor, 1968, *Microcaeilia* Taylor, 1968 and *Parvicaecilia* Taylor, 1968 (Amphibia: Gymnophiona: Siphonopidae) *Occ. Pap. Mus. Zool., Univ. Michigan,* No. 744, pp. 1-10, 2 figs., 1 table.

Smith, G.R., J.D. Stewart & N.E. Carpenter. 2013. Fossil and Recent mountain suckers, *Pantosteus*, and significance of introgression in catostomin fishes of the western United States. *Occ. Pap. Mus. Zool., Univ. Michigan,* No. 743, pp. 1-59, 12 figs., 2 appendices, supplementary material.

Lindsay, A.R. & S.C.G. Haas. 2013. DNA from feces and museum specimens confirms a first state record bird. *Occ. Pap. Mus. Zool., Univ. Michigan,* No. 742, pp. 1-10, 4 figs., 1 table.

Oldfield, R.G. 2009. Captive breeding observations support the validity of a recently described cichlid species in Lake Apoyo, Nicaragua. *Occ. Pap. Mus. Zool., Univ. Michigan,* No. 741, pp. 1-14, 6 figs., 3 tables.

COVER PHOTOGRAPH— Quarry aerial photo by James E. Martin©

FOSSIL FISHES FROM THE MIOCENE ELLENSBURG FORMATION, SOUTH CENTRAL WASHINGTON

by

Gerald R. Smith, James E. Martin, and Nathan E. Carpenter

FOSSIL FISHES FROM THE MIOCENE ELLENSBURG FORMATION, SOUTH CENTRAL WASHINGTON

By

Gerald R. Smith[1,3], James E. Martin[2], and Nathan E. Carpenter[3]

ABSTRACT

The Granger Clay Pit fossil fish fauna is from the Middle Miocene Ellensburg Formation near the Yakima River in Yakima County, Washington. Seven genera of fishes in four families were collected by Kevin Meeks and James E. Martin, mostly from interbedded clay and tephra in a green claystone near the old clay pit workings. Catfish (Ictaluridae, *Ameiurus* new species) and sunfish (Centrarchidae, *Archoplites*) are the most common species; minnows (Cyprinidae) are the most diverse family. The Ellensburg cyprinid assemblage includes a new species of *Mylocheilus*, rare *Ptychocheilus* and *Klamathella*(?), and early *Rhinichthys,* as well as a plagopterin spine dace, otherwise known from the Lower Colorado drainage. The sucker, *Pantosteus* (Catostomidae), is known earlier in the Drewsey-Juntura Basin and has a subsequent history in Columbia-Snake River, Colorado River, and Great Basin drainages. Each faunal element is unique in its timing and direction of relationships, suggesting assembly of the fauna during a long prior history in the basin of the Columbia Plateau Province.

INTRODUCTION

The Ellensburg Formation was named for sediments deposited in the Kittitas Valley along the Yakima River near Ellensburg, Washington (Russell, 1893, 1900). Similar beds are present to the south along the leeward front of the emerging central Cascade Mountains; including the Nile, Selah, Yakima, and Toppenish basins. Farther south along the Columbia River, portions of the Dalles Group, Rhododendron Formation and Sandy River Mudstone, are likely temporal equivalents, found on the leeward side of the uplifting Cascade Range (Farooqui et al., 1981; Evarts et al., 2009).

The type section for the Ellensburg Formation is located in sections 27 and 34, T. 19 N., R. 17 E. (47.09 North latitude, 120.69 West longitude) near Dudley, Washington, along the eastern side of the Yakima River. Smith and Campbell (1989) presented a K/Ar date of 10.53±0.37 Ma from 25 meters below the contact with the overlying Pliocene Thorp Gravel (3.6–4.4 Ma). The complex history of the Ellensburg Formation was summarized by Martin and Mallory (2011).

Fossil leaves collected by J. S. Diller and I. C. Russell in 1893 from the southern end of Kittitas Valley (Bull Quarry) were assigned to 10 species, including willow, poplar (*Populus russelli*), elm, sycamore, and magnolia, indicative of a much milder local climate than today (Knowlton in Russell, 1893; Russell, 1900). Knowledge of the Ellensburg flora was significantly expanded by Beck (1945), Smiley (1963) and Pigg and Wehr (2002). Smiley (1963) recognized a sequence of floras in the Ellensburg Formation that transitions from a mesic bottomland to a xeric streamside.

Bull Quarry also produced the first reported vertebrate fossils from the Ellensburg Formation, *Hipparion condoni* (Merriam, 1915; Beck, 1946). Additional vertebrate fossils including turtle, tortoise, horses, rhinoceroses, proboscideans, camels, antelopes, peccary, canid, felid, and rodents were reported from this formation (Merriam and Buwalda, 1917; Osborn, 1936; Chappell et al., 1951; Warren, 1941; Beck, 1945, 1946; Shotwell, 1961; Foxworthy, 1962; Smiley, 1963; Black, 1963; Schmincke, 1964; Bryant, 1968; Edwards, 1976; Gustafson, 1978; Martin and Tedrow, 1988; Lindsey, 1996; Prothero, 2005; Martin and Pagnac, 2009; Martin and Mallory, 2011; Martin, 2014). Prior to the work of Martin and associates, the primary source of vertebrate fossils was the Granger Clay Pit and miscellaneous finds of uncertain provenance.

[1] University of Michigan, Ann Arbor, MI 48108 (grsmith@umich.edu)
[2] Geology Museum, University of Louisiana, Lafayette, LA 70504
[3] Orma J. Smith Museum of Natural History, College of Idaho, Caldwell, ID 83605

THE GRANGER CLAY PIT

The Granger Clay Pit (Fig. 1) was a source of building material for the booming central Washington region from 1903 to the 1960s, during which many plant and animal remains were uncovered. Schmincke (1964) detailed the surface geology of the region and reported a 105m–15m section of upper Ellensburg sediment locally overlain by conglomerate at the Granger Clay Pit. G. A. Smith (1988a, b) reported an age of 10.28±0.28 Ma for upper Ellensburg volcanoclastic sediments in a 50 m section at Granger and suggested they must lie above 10.5 Ma normal magnetic polarity Elephant Mountain Basalt (McKee et al., 1977). The section at Granger is detailed in Smith's (1988a) figure 16, showing the ancestral Yakima River facies deposits. The siliciclastic conglomerates near the top are often referred to as the Snipes Mountain Conglomerate and are interpreted as the result of deposition by the ancestral course of the Columbia River. Smith and Campbell (1989) considered the Snipes Mountain Conglomerates to be equivalent to the basal Ringold Formation above the 8.5 Ma Ice Harbor Basalt in nearby Pasco Basin (McKee et al., 1977).

In 1920, a nearly complete proboscidean skeleton was collected from the Granger Clay Pit and was displayed for a time at the University of Washington Burke Museum (UWBM). The UWBM catalogue lists three Proboscidea from this locale, *Zygolophodon tapiroides*, *Rhynchotherium brevidens*, and *Gomphotherium angustidens*; the first two were collected in 1920 and the third in 1925 (Osborn, 1936), but lithostratigraphic levels are unknown. The gomphothere is considered to represent *Gomphotherium productum*(?), normally found in Barstovian assemblages, and the mastodons are now termed *Zygolophodon proavus* (Lambert and Shoshani, 1998; Lucas and Morgan, 2008). Hough (in Foxworthy, 1962) also reported *Z. proavus* as *Miomastodon merriami* from sediments just above the 12 Ma reversed magnetic polarity Pomona Basalt in the Roza Canal tunnel at Yakima Ridge (McKee et al., 1977; Lambert and Shoshani, 1998). These specimens require restudy to confirm taxonomic identification before their biostratigraphic utility can be determined.

George Beck, formerly of Central Washington College, sent a large collection of fossils from the Granger Clay Pit to Chester Stock at the California Institute of Technology (now the Los Angeles County Museum, LACM) from 1935–1963. In these collections Bryant (1968) identified a large tortoise, medium-sized camel, large camel, a large mustelid (*Beckia grangerensis*), horse (*Hipparion anthonyi* (?)), and an antilocaprid. *Beckia* was transferred to *Hoplictis* (Tedford et al., 1987; Baskin, 1998), which ranges from the Hemingfordian to Clarendonian-equivalent NALMA ages of Europe and late Clarendonian to earliest Hemphillian of California and Florida; the Granger Clay Pit specimen being the oldest documented North American example. Tedford et al., (2004: 210) utilized the first appearance of *Hoplictis* as part of the definition of the late Clarendonian (Cl3). *Hipparion anthonyi* was named for a

lower horse tooth from the Clarendonian Ironside Formation, Oregon, based on complex enamel flexures (Merriam, 1916). Specimens from the Clarendonian Poison Creek Formation of Idaho and the Hemphillian Rattlesnake Formation of Oregon were also tentatively assigned to this species (Merriam et al., 1925). MacFadden (1984) considered *Hipparion anthonyi* to be a *nomen dubium* and suggested it is probably *Cormohipparion sphenodus* or *C. occidentale*. Woodburne (1996, 2007) placed eastern North American late Barstovian *C. sphenodus* in the genus *Merychippus*, which leaves Barstovian to Clarendonian *Cormohipparion* cf. *occidentale* the most likely candidate for the Granger specimens (similar to specimens reported from Poison Creek Formation in the Western Snake River Plain of Idaho and Salt Lake Formation near Trapper Creek, Idaho). Beck also noted the presence of this larger species in upper Ellensburg sediments at Squaw Peak in the Selah Basin as well as "*Pliohippus*" sp. (Beck, 1938; Shotwell, 1961). The LACM catalog lists a right dentary of *Pliauchenia* cf. *singularis* from the Granger Clay Pit, which subjectively became *Paramiolabis* cf. *singularis* based on Kelly (1992) and Honey et al., (1998). The biostratigraphic range of this camelid is normally in the Barstovian, similar to that of the proboscideans.

Several institutional collections contain cheek teeth from *Hipparion condoni* recovered from the Granger Clay Pit. The LACM collections contain a left ramus and other cheek teeth. MacFadden (1984) considered *Hipparion condoni* to be a *nomen dubium* based on a presumed lost type specimen, no reference material, and unknown type locality. The type local is now understood (Beck, 1946), the type specimen is in the Condon Museum at the University of Oregon (Gustafson and Eaton, 1983), and sufficient collections are available to recognize the species, which has priority over *Hipparion forcei* (Martin and Pagnac, 2009). *Hipparion forcei* is common in the Ricardo Fauna, Mohave Desert, California from the medial to late Clarendonian (Whistler et al., 2009).

Martin (2014) described a lower jaw of the enigmatic insectivore, *Plesiosorex* cf. *latidens* from the Meeks Quarry. The specimen represents the most northerly occurrence of the plesiosoricid in North America. *Plesiosorex latidens* is found associated with Clarendonian paleoassemblages. Additional fossils have been recovered from the quarry, and this suite of mammals may indicate a more precise Clarendonian assignment of the paleofauna associated with the fishes described herein.

The previously collected fossil specimens from the Granger Clay Pit present obstacles to understanding the age of the deposits based on mammalian biostratigraphy. Except for *Plesiosorex*, none of the taxa described above came from the Meeks Quarry level; the others do not have precise lithostratigraphic provenience and were undoubtedly found at different levels. The known biostratigraphic ranges of the taxa are contradictory and contradict what is generally thought to be the geochronological ages assigned to the land mammal ages (Tedford et al., 2004). All of the original specimens collected
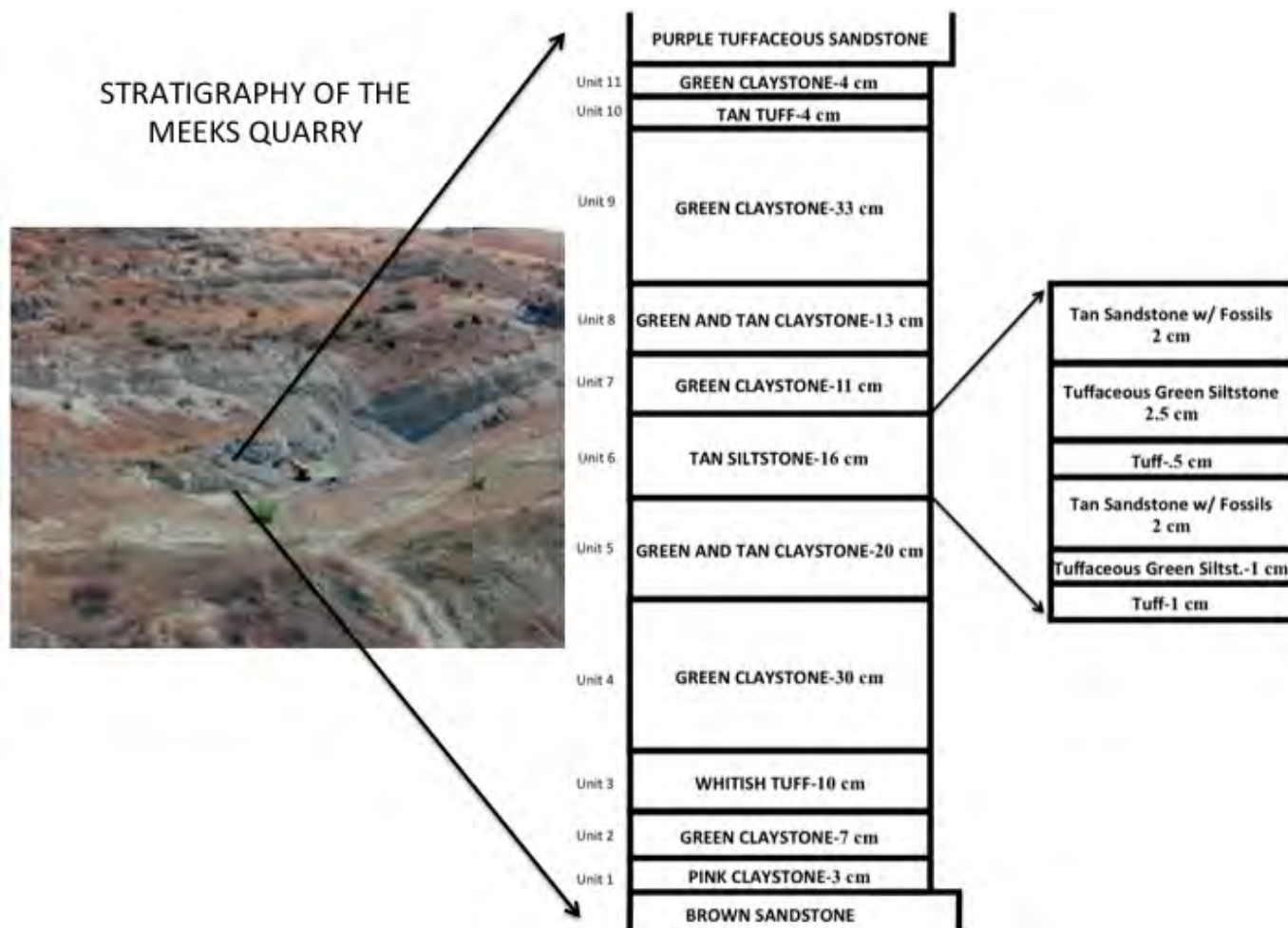
Figure 1.— Stratigraphic context for the Meeks Quarry in the Granger Clay Pit locality.

from the Granger Clay Pit require restudy to determine precise taxonomic identifications. Until that time, the currently identified proboscideans and *Pliauchenia* cf. *singularis* from Granger most commonly occur with Barstovian assemblages, typically thought to range from 15.97–13.6 Ma. The carnivore, *Hoplictis*, ranges in North America from the late Clarendonian (thought to be ~9–10 Ma) into the early Hemphillian (~7–9 Ma), and Tedford et al., (2004) considered its first appearance as indicative of the late Clarendonian. If the hipparion specimens are actually *Cormohipparion* cf. *occidentale*, the range of this taxon is Barstovian to Hemphillian (~16–7 Ma), and *Hipparion condoni* appears to be medial and late Clarendonian (~12–9 Ma). Overall, the composite ranges of the taxa discussed above extend from Barstovian to early Hemphillian, a duration of approximately 9 million years, and based on these range disparities, precise land mammal age assignment is premature. Moreover, ranges in the Pacific Northwest may well be at variance of those in Florida, the Great Plains, or even California. Until such provincialism is precisely understood, the radiometric dates assigned to

NALMAs elsewhere may not reflect the situation in the Pacific Northwest. As a result, radiometric dates from the Granger Clay Pit, if reliable, are currently the only source for the age of the deposits at the Granger Clay Pit, and these suggest deposition after the 10.5 Ma Elephant Mountain Basalt at approximately 10.28±28 Ma (Smith, 1988a,b).

OTHER IMPORTANT ELLENSBURG FORMATION VERTEBRATE LOCALS

Hough (in Foxworthy, 1962) listed a camel, *Pliauchenia merriami* (?), from below the Wenas Basalt in the Roza Canal tunnel through Yakima Ridge. Harrison (1985) named *Megacamelus merriami* for late Hemphillian large camels with the type specimen from Mount Eden Formation, California. This may be the same large camel found at the Granger Clay Pit and should be restudied for precise taxonomic assignment.

Edwards (1976) listed *Nannippus* aff. *tahoensis* from below the Wenas (Pomona) Basalt near Zilla, Washington, which MacFadden (1984) considered to be *Neohipparion*

trampasense. *Neohipparion trampasense* is known from medial Clarendonian to early Hemphillian. It is found in association with *Hoplictis grangerensis* in the late Clarendonian Kendall-Mallory local fauna of Contra Costa, California (Baskin, 1998).

A bone-chewing dog, *Epicyon* sp.*,* was listed from the Ellensburg Formation at the north end of Selah Basin at the entrance to Yakima Canyon (Martin and Tedrow, 1988). The USNM online catalog lists this specimen along with skull material provided by Beck as *Osteoborus diabloensis*. These specimens along with similar material from the lower part of The Dalles Group (Chenoweth Formation, Oregon) were included in *Epicyon saevus* (Wang et al., 1999). Although similar specimens are known from the Clarendonian Juntura Formation, Oregon (Orcutt and Hopkins, 2011), the range of *Epicyon saevus* extends from throughout the Clarendonian to the late Hemphillian.

Shotwell (in Smiley, 1963), and Martin and Tedrow (1988) listed a felid, *Pseudailurus*, from Granger at the Roza Canal near Buena, Washington. This specimen is much larger than most *Pseudailurus* species and modern *Puma concolor*. It could be more closely related to Asian *Pseudailurus* sp. or a new North American species.

The Tyrell Quarry from the Selah-Naches hills produced turtle, horse (*Hipparion*), and rhinoceros fossils associated with a large flora (Beck, 1946; Smiley, 1963). Prothero (2005) identified the rhinoceros as *Teleoceras majori*, which he considered characteristic of the Clarendonian NALMA. Evernden and James (1964) reported a K/Ar date of 10 Ma for the floral local near the top of the section.

Martin and Pagnac (2009) described the Babcock/Foisy local fauna from Rattlesnake Ridge north of Granger, low in the section between the Elephant Mountain and Pomona basalts. The collection includes *Hipparion condoni*, *Teleoceras* cf. *majori*, antelope (*Cosoryx* cf. *cerroensis*), lamini camel, paleomerycid (*Cranioceras* cf. *unicornis*), canid (*Cynarctus* nr. *crucidens*), mustelid (*Leptarctus*), and a turtle. These authors assigned a late Clarendonian age to the assemblage based upon the ranges of the antelope, paleomerycid, and canid species. However, the stratigraphic position between the Pomona Basalt (12 Ma) and Elephant Mountain Basalt isotopically dated at 10.5 Ma (Madin, 2009) suggests a somewhat older time of accumulation. Therefore, this site may indicate a disparity between biostratigraphic and geochronologic scales in the Pacific Northwest compared to other regions in North America. However, the tentative species designations may also explain the disparity.

In general, the Ellensburg mammals suggest a Clarendonian biota of fairly uniform composition. Several of the genera are known from Eurasia as well as southern California. The appearance of *Cormohipparion*-like horses in Eurasia ca. 12 Ma and *Hipparion* horses ca. 11 Ma suggest that the Ellensburg horses may represent important evidence for Holarctic faunal exchange.

PREVIOUSLY REPORTED FOSSIL FISHES FROM THE AREA

The oldest reported fish paleofauna from the region is from the Eocene of Republic, Washington. Five species of Atlantic-drainage fish are reported from the Republic area: *Amia hesperia* (bowfin), *Eohiodon woodruffi* (mooneye, goldeye), *Amyzon aggregatum* (sucker), *Eosalmo driftwoodensis* (salmonid), and *Libotonius pearsoni* (troutperch). The habitat is considered to have been shallow freshwater lakes. The paleofauna is most similar to Eocene paleofaunas in British Columbia, Montana, Wyoming, and Colorado (Wilson, 1996).

A climatic cooling at the end of the Eocene resulted in the regional Eocene fish paleofaunas being eliminated. It was not until the medial Miocene ca. 15.9 Ma that a new, diverse local fish paleofauna appeared: including specimens from Latah, Clarkia, and lower Ellensburg formations. Fish were reported from the 15.9–14.3 Ma Latah Formation as minnows and sunfish but no detailed report is available. The 15.9 Ma Clarkia fishes reported by Smith and Miller (1985) includes *Paleolox* sp. (char), *Siphateles* sp. (chub), and *Archoplites clarki* (small sunfish). The 15 Ma Squaw Creek Diatom Member of the Ellensburg Formation produced scales from a large sunfish identified by David Dunkle (in Schmincke, 1964) as "*Plioplarchus*" *septemspinosus* and a slightly younger interbed in the Priest Rapids Basalt Member of the Columbia River Basalt produced *Ptychocheilus* sp. (pikeminnow) (Smith et al., 2000).

Late Miocene and Pliocene fish fossils are abundant in the overlying Ringold Formation. The lowest fish-producing member in the Ringold Formation is the Taylor Flat Conglomerate, which produced giant salmon, *Oncorhynchus rastrosus*. That member lies above an ash dated at 6.7 Ma (Lindsey, 1996) and below the overlying early Blancan White Bluffs local fauna; suggesting a late Hemphillian NALMA. The fact that the White Bluffs local fauna lies just above the Taylor Flat Conglomerate member also suggests that the associated paleofauna is closer to the younger age. This locality is similar in age to other localities from north central Oregon such as Krebs Ranch, Arlington, Boardman, McKay Reservoir etc., which produced pikeminnow, Muskellunge, and *Oncorhynchus rastrosus*. Two more fish paleofaunas occur in the Ringold Formation above the White Bluffs local fauna: Bluff Top (ca. 3.7 Ma) and Taunton Bench (ca. 3.0 Ma).

Here we present the first record of a small but distinct fish assemblage with a catfish, five kinds of minnows, a sucker, and a sunfish collected by Kevin Meeks and James E. Martin from the Granger Clay Pit in the upper part of the Ellensburg Formation. Disarticulated vertebrate fossils preserved in about 2 m of pale tephra are assigned to Late Miocene Clarendonian. The fishes from the Granger Clay Pit share six genera and four species with the older Juntura and nearby, but younger, White Bluffs paleofaunas.

FOSSIL FISHES OF THE UPPER ELLENSBURG FORMATION

At least seven kinds of fishes in four families were collected by Kevin Meeks and James E. Martin, mostly from the interbedded clay and tephra (unit 6) of a green claystone that occurs near the base of the upper exposed section (Fig. 1) from the Meeks quarry above the old clay pit workings. Catfish (Ictaluridae, *Ameiurus*) and sunfish (Centrarchidae, *Archoplites*) are the most common species; minnows (Cyprinidae) are the most diverse family. The Ellensburg cyprinid assemblage includes Columbia River drainage cyprinid genera, *Mylocheilus*, *Ptychocheilus*, *Klamathella*(?), and *Rhinichthys,* as well as one extreme range extension, a plagopterin spine dace, a group which inhabits the Lower Colorado drainage in the Great Basin. *Pantosteus* is a sucker (Catostomidae) with a long history in the Columbia River, Colorado River, and Great Basin drainages. Fishes were obtained by disaggregating the clay in water and gently screening or picking the fossils from among the shards of tephra.

TELEOSTEI
SILURIFORMES
ICTALURIDAE
Figs. 2, 3, 4

Ameiurus, Bullhead Catfish.— Small catfish pectoral spine fragments and other bones are rather common in sediment samples. Dorsal spines, cleithral articulations, dorsal pterygiophores, and an articular-angular are included. Pectoral spines are usually smaller than 15 mm long, indicating smaller body size than adults of Eastern and most other Western *Ameiurus nebulosus*. The spines differ in their pattern of longitudinal striations, posterior denticles, and anterior denticulations sufficiently to be recognized as a distinct species.

Ameiurus grangerensis new species
Figs. 2, 3, 4

Holotype.— A proximal two-thirds of a pectoral spine (SDSM 86765) 15.6 mm long, showing 12 rather straight (except distally), sharp, unbranched denticles, and numerous small anterior denticulations; the shaft is 2.2 mm thick, antero-posteriorly at its thickest point near the dorsal articulating process. The dorsal articulating process is robust with fine striations on its edges and proximal face. The ends of the anterior and ventral processes are blunt, not pointed, with striations for sound production facing the antero-ventral emargination. Similar striations are on the lateral and central bases of the dorsal spine and the posterior-facing dorsal wings of the dorsal-spine. There are no more than three denticles in the space of one spine width at about the center of the shaft (Fig. 2b).

Type Locality.— From the Granger Clay Pit, (unit 6, Fig. 1) Ellensburg Formation, south of Granger, Washington, eastern Toppenish Basin, ULGM locality V19, 259 m elevation.

Diagnosis.— *Ameiurus grangerensis* is known primarily from pectoral spines with single-pointed, long, sharp retrorse denticles, which are slightly recurved; denticulations spaced about 2–3 per spine width locally; and weak anterior denticulations (Fig. 2, 3, 4). The pectoral spines have a wide proximal third like *Ameiurus reticulatus,* the Ringold catfish, but with a slender shaft and single-pointed denticles like *A. vespertinus* of the Western Snake River Plain, not *A. peregrinus* of the Drewsey-Juntura basin. The proximal side of the base has a complex, three-basin topography and fine striations (Fig. 2). The textures of bone surfaces of *A. grangerensis* are not reticulate, unlike the White Bluffs and Taunton species (Smith et al., 2000).

Description.— Bullhead Catfish with simple (unbranched) denticulations that are wide at the base, retrorse but not much recurved, their frequency is slightly over two denticulations per spine width; small, weak, anterior denticles; strong longitudinal ridges and grooves (Fig. 3), well-developed basal topography of the dorsal articulating process, with striations for sound production, and low-angled sharp distal ends.

Paratypes.— Pectoral spines (Fig. 2, 4). SDSM 86755, four dorsal spines, and one left articular angular (Fig. 4).

Etymology.— Named for the Granger Clay Pit, Ellensburg Formation, near Granger, Yakima County, Washington.

Material examined.— ULGM V3499, 21 pectoral spine fragments, <24 mm; five dorsal spines, <22 mm. ULGM 3492, two partial dentaries, 12, 10 mm. ULGM V5491, 19 pectoral spine fragments <20 mm, five dorsal spines <22mm long. Only the largest of these spines represent specimens as large as average-size eastern North American *Ameiurus nebulosus*; one opercular fragment. Meeks collection, 42388, eight pectoral spines <22mm long; two dorsal pterygiophors; one cleithral fragment.

Comments.— *Ameiurus* is a bullhead catfish related to eastern North American Ictaluridae (Arce-H. et al., 2016). It was widespread from central Washington, the Columbia and Snake Rivers, and the Truckee Formation of Nevada in the Miocene and Pliocene. Its abundance and size suggest a small, low-gradient stream habitat. Few bones are unbroken. The concentration of tephra and clay and the small size of the fragments also suggest deposition in small outwash stream sediments of a remote explosive volcanic event.

CYPRINIFORMES
CYPRINIDAE
Ptychocheilus sp.
Fig. 5a, b

A single large tooth of a pikeminnow (SDSM 86761) is recognizable as *Ptychocheilus* by its large size, rounded cross-section, robustness, and reduced terminal hook (Fig. 5a, b).
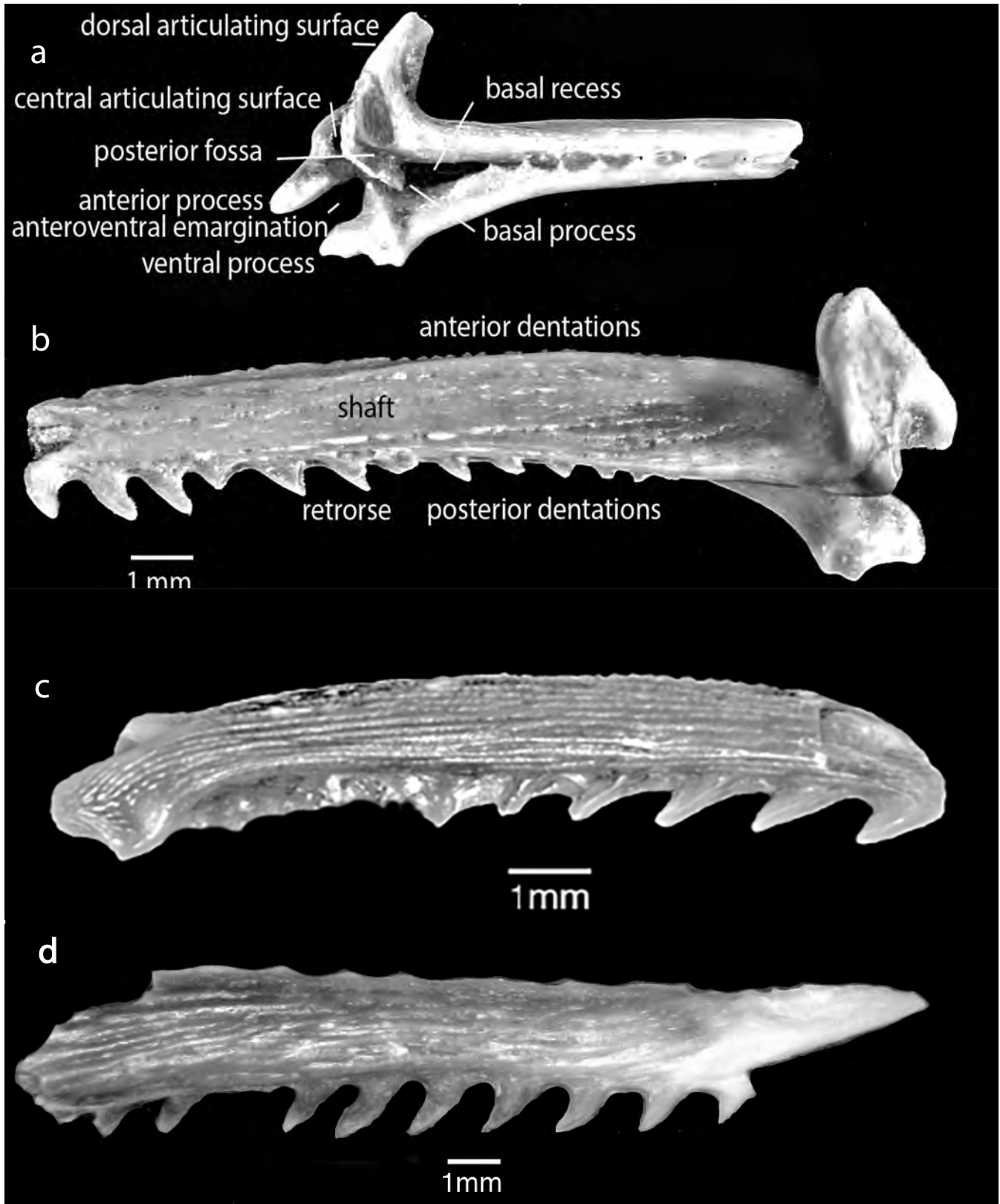
Figure 2.— **a,** Pectoral spine terminology (Terminology after Hubbs and Hibbard, 1951); **b,** holotype (SDSM 86765) of *Ameiurus grangerensis*; **c, d,** two pectoral spine fragments of adult *Ameiurus grangerensis (*SDSM 86743, 86754).
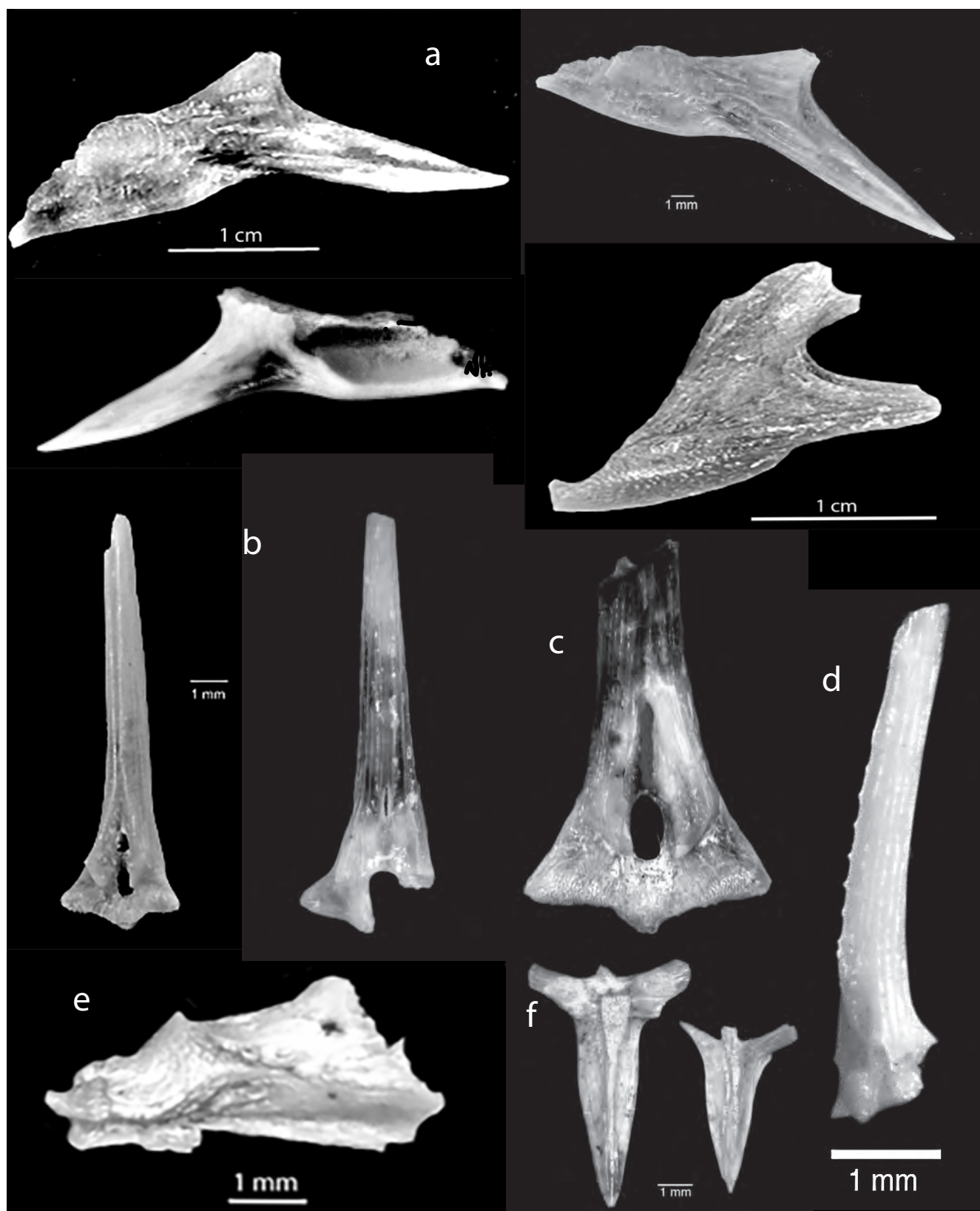
Figure 3.— Paratypes of *Ameiurus grangerensis.* SDSM 86755, **a,** four fragments of cleithra; **b,** two dorsal spines, posterior and anterior; **c,** posterior view; **d,** left lateral view; **e,** left articular angular, mesial view; **f,** two dorsal pterygiophores (SDSM 86757).

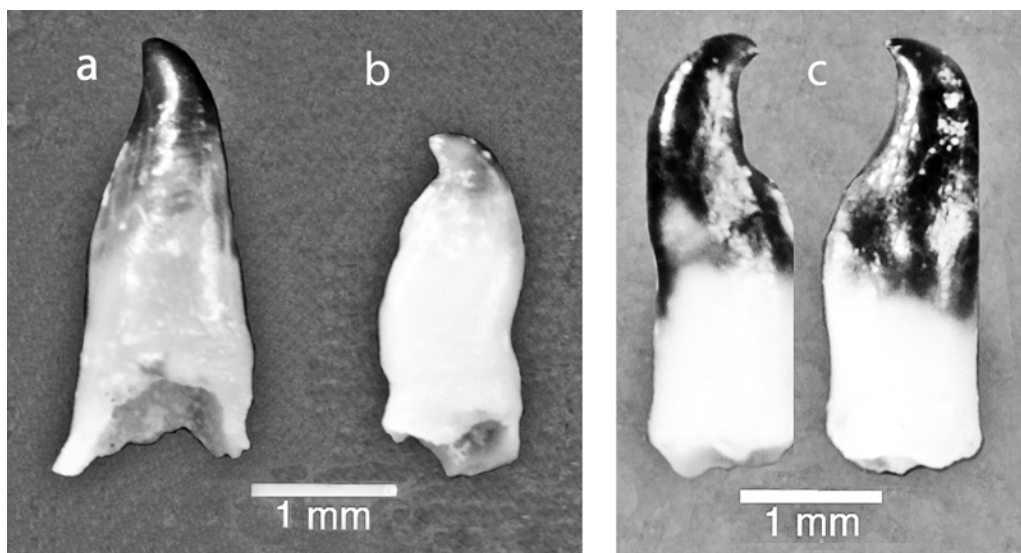Figure 4.— Variation in pectoral spines of *Ameiurus grangerensis* (SDSM 86754).

Figure 5.— **a,** *Ptychocheilus* sp. (SDSM 86761 part); **b,** *Klamathella*(?) sp. (SDSM 86761 part); **c,** unidentified cyprinid with robust teeth and large terminal hooks (SDSM 86761 part).

It was accompanied by a large posterior fragment of a long, pointed left pharyngeal arch of *Ptychocheilus* with one large posterior tooth socket. The arch would have been over 25 mm long, indicating a fish over 35 cm long. *Ptychocheilus* is uniquely larger than any other North American cyprinids. It was the top fish predator, occurring in most warm-water assemblages in Late Cenozoic of the inland Northwest, including the Ringold Formation (Smith et al., 2000). The Columbia Pike Minnow has a continuous history in the Columbia drainage—an older pharyngeal arch with teeth was found by geologist Steve Reidel from basalts dated at about 15 Ma near Priest Rapids Dam. *Ptychocheilus* now occurs in the Columbia-Snake, Colorado, Sacramento, and Umpqua rivers. Some populations occurred in the Great Basin in the Miocene and Pliocene (Smith et al., 2002). *Ptychocheilus* is monophyletic, although neutral DNA markers are polyphyletic. *Ptychocheilus* teeth do not have strong terminal hooks; their 15 Ma ancestors were already large top predators (Smith et al., 2000). Specimens from the Middle Miocene Sucker Creek Formation in the Oregon-Idaho Graben (OIG) were smaller, with proportionally smaller jaws (Carpenter and Smith, this volume.)

Material examined, SDSM 86747, partial pharyngeal arch; SDSM 86761, several large teeth lacking terminal hooks; several large fragments of pharyngeal arches and other bones.

Unidentified cyprinid sp.
Fig. 5c

Medium-sized, unidentified cyprinid teeth (SDSM 86761) with moderately strong terminal hooks possibly represent relatives of *Klamathella*—a moderate-sized northwestern genus with tooth form remotely like that seen in Fig. 5c.

These were medium-sized predators in warm-water habitats in the Northwest. *Pogonichthys* is a similar-sized, plesiomorphic cyprinid with roughly similar teeth lives in the Sacramento River drainage. Miocene to recent cyprinids with similar teeth in the Northwest are *Gila* and *Couesius*.

Mylocheilus kevinmeeksi new species.
Fig. 6

Holotype.— A partial pharyngeal arch, 8.5 mm long, with two molariform teeth, 2.5 and 3 mm long (Fig. 6e, SDSM 86743).

Type Locality.— From the Granger Clay Pit, (Unit 3, Fig. 1) Ellensburg Formation, south of Granger, Washington, eastern Toppenish Basin, ULGM locality V19, 259 m elevation.

Diagnosis.— A species of *Mylocheilus*, based on the molariform pharyngeal teeth (Fig. 6g) and the short pharyngeal arch with a short, tightly curved radius, and a sharply-angled anterior process (Fig. 6c). *Mylocheilus kevinmeeksi* differs from *M. kingi*, *M. robustus,* and *M. caurinus* in having four or fewer teeth in the main pharyngeal row, angled to grind against the basioccipital pad rather than opposing teeth, and reduced to two teeth in late replacement cycles, as teeth two and three grow allometrically to fill the tooth-row space on the arch. *Mylocheilus kevinmeeksi* differs from *M. inflexus* and *M. whitei* arches in having a more compact shape—short anterior and post-dorsal processes and robust, rounded ventro-lateral body of the pharyngeal arch, as in *M. robustus* and *M. kingi*. The shape of the arch and orientation of the teeth imply similarity to *Mylocheilus robustus* and *M. kingi,* which have mesial, opposing orientations, not plesiomorphic dorsal orientation as in *M. inflexus* or *M. whitei*.
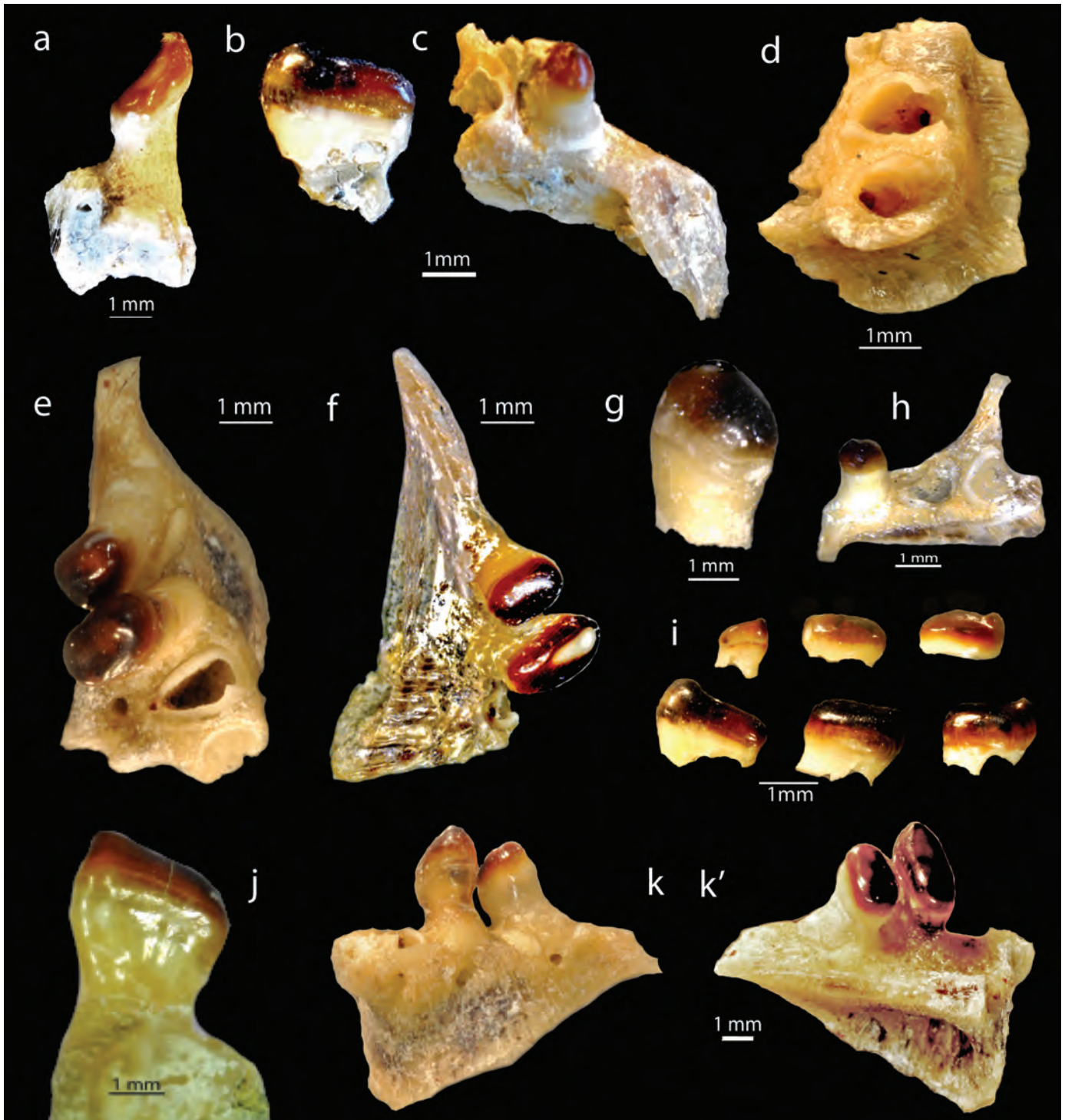
Figure 6.— *Mylocheilus kevinmeeksi*. **a,** fourth and last (posterior) tooth of right pharyngeal arch (SDSM 86749), anterior view; **b,** second or third tooth (SDSM 86749); **c,** first tooth on anterior limb, with symphysis (SDSM 86749); **d,** left pharyngeal arch fragment (dorso-mesial view, anterior up, ventral right) showing enlarged empty tooth bases for second and third teeth, first and fourth teeth not replaced (SDSM 86749); **e,** left pharyngeal arch fragment (dorso-lateral view, anterior up, ventral right) showing molariform first tooth and second molar and empty bases for teeth three and four of holotype of *Mylocheilus kevinmeeksi* (SDSM 86743); **f,** left pharyngeal arch fragment (dorsal view, anterior up) angle of orientation of symphysis and teeth indicate tooth opposition to basioccipital pad (SDSM 86759); **g,** tooth one (SDSM 86749); **h,** symphysis and tooth one (on left), empty bases for teeth two three, and four with fragment of post dorsal process (on right) (SDSM 86747); **i,** variation in teeth (SDSM 86749); **j,** advanced fourth tooth showing orientation of flat grinding surface (SDSM 86749); **k,** lateral view, and **k',** mesial view of left pharyngeal with teeth numbers one and two of four ( ).
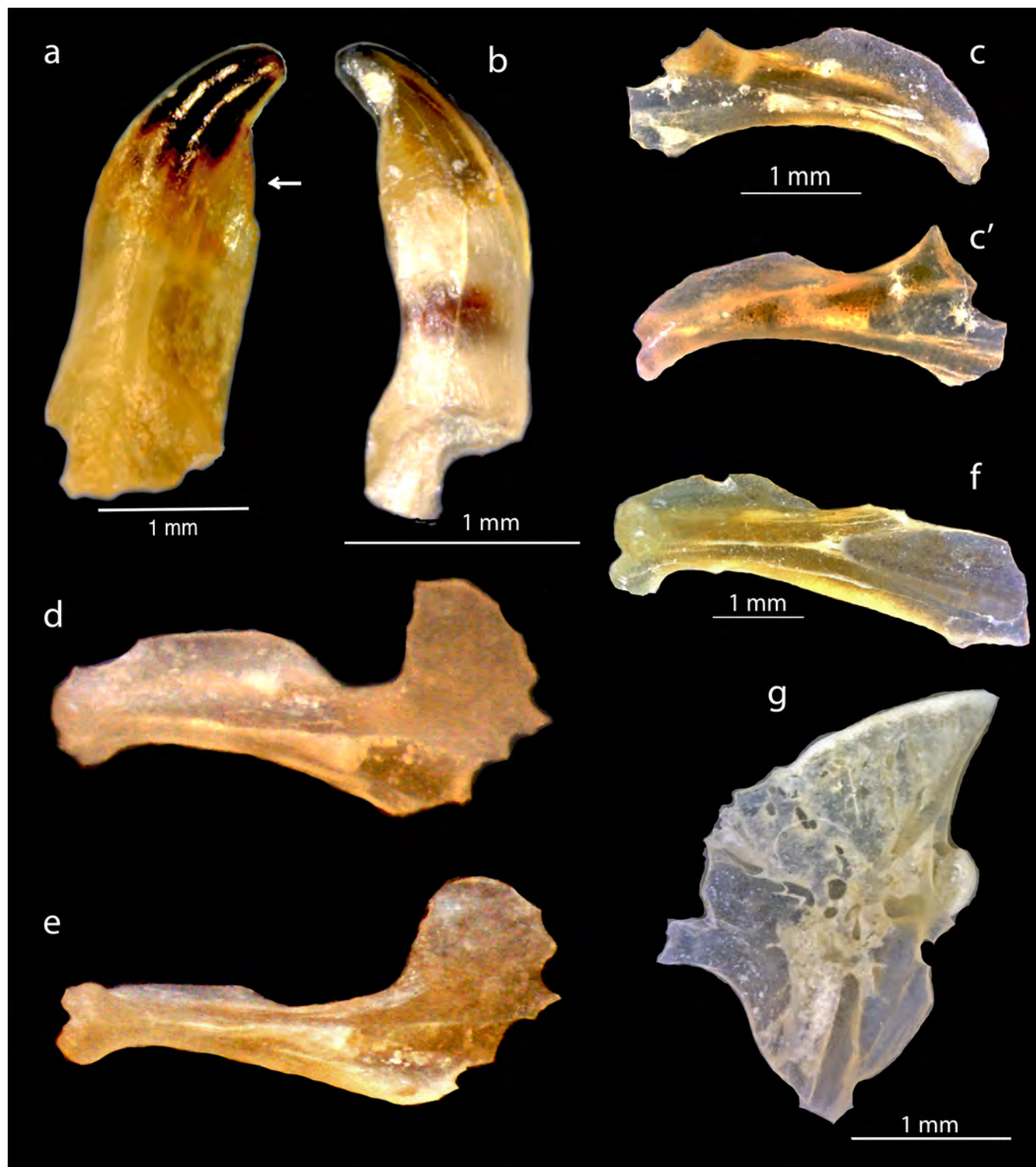
Figure 7.— *Rhinichthys* sp. **a, b,** pharyngeal teeth; **c, d, e, f,** right dentaries; **g,** hyomandibula (SDSM 86748).

Description.— *Mylocheilus kevinmeeksi* is known only from the pharyngeal arches and teeth (Fig. 6), which are abundant in the sample from the Granger Clay Pit. The pharyngeal tooth formula is ~1,4–4,~1: four teeth in each primary row and one small tooth variably present in the inner row. The first (anterior) tooth in the primary row is small and conical in early stages of cyclic tooth replacement, the second and third teeth are large and molariform and positively allometric, the fourth tooth is hooked in early stages. The first and (or) fourth teeth may be lost in later (of six) replacement cycles. The teeth are asymmetrical in the mesial orientation of the grinding surface relative to the main axis and base of the tooth (Fig. 6c, d, e, f, h, k'), consistent with their function in grinding mesiad toward opposing teeth. *Mylocheilus kevinmeeksi* is the smallest fossil species in the genus, but is comparable to the size of modern Peamouth Chub, *Mylocheilus caurinus* of the Columbia River Basin (Wallace and Zaroban, 2013).

Paratypes.— Seventeen pharyngeal arches and teeth, SDSM 86760 (Fig. 6a, b, c, d, f, g, h, I, j, k).

Etymology.— Named for Kevin Meeks, who collected thousands of fossil fish bone fragments from the locality he developed in the Granger Clay Pit.

Material examined.— Meeks collection, UMMP 42389, one partial pharyngeal arch, 9.8 mm, with one tooth and partial posterior process (figured), one partial arch 6.3 mm,10 teeth <2.8 mm; two dentaries, 3.3,3.1 mm, one hyomandibula 4.0 mm. From matrix, *Mylocheilus* arches with two teeth, arches are 8 and 10 mm long; nine teeth, largest 4 mm long across crown; three isolated teeth (not photographed).

Comments.— *Mylocheilus* fossils are known from the Granger Clay Pit and Miocene-Pliocene Columbia-Snake river drainages, south to the Pliocene Bouse Formation (Reynolds et al., 2016).

Rhinichthys sp.
Fig. 7

A small tooth, 2.6 mm long (Fig. 6) has the diagnostic blade on the cutting edge. Traits of other teeth seem to overlap with minnow teeth possessing elongate and concave grinding surfaces, which by elimination should be assignable to the plagopterin minnow in the fauna. *Rhinichthys* and the plagopterin are the only diminutive minnows in the assemblage. *Rhinichthys* has large terminal hooks (Fig. 6). The grinding teeth in Fig. 6 and 7 appear to be either a plagopterin or *Rhinichthys* in an early, variable, stage of evolution of the sharp cutting blade.

The dentary of *Rhinichthys*, like plagopterins, has a short, antero-laterally flattened biting edge rather than an upward curve to the biting edge, and an absence of the typical cyprinid ventral sensory pore series. The hyomandibula (Fig. 7g) has a long, concave gap between the opercular condyle and the post-dorsal point of the dorsal condyle.

Material examined.— SDSM 86748, Two teeth with convex cutting blades, 4.4, 2.2 mm; two right dentaries, 3.6, 2.2 mm.; two sharp teeth, 0.7 mm between points; from matrix, one dentary, short, stubby, 2.6 mm long, with flat biting edge, no ventral sensory pores. Meeks collection, UMMP 42390, one tooth, 2.8 mm; nine dentaries, 5.5–2.2 mm with no ventral sensory pores; two small fragments of pharyngeal arches, 2.4, 1.8 mm.

cf. *Lepidomeda* sp.
Figs. 8, 9

Plagopterin spines and teeth are common among the fossils collected by Mr. Meeks. We do not yet have an understanding of the variation in the Granger cf *Lepidomeda* dentaries and teeth (Fig. 9) relative to the dentaries and teeth of ancient *Rhinichthys* (Fig. 8), but the plagopterin pelvic fin spines (Fig. 9) are unique among fishes in the nipple-like process on the proximal end and the minute incipient rays at the distal end. The pelvic pterygiophore is robust compared to that of *Rhinichthys* (Fig. 9). Most have 2,5–4,2 teeth; most of the recent forms have cutting blades but most of the fossils have concave grinding surfaces (Fig. 9).

Material examined.— SDSM 86746, 21 spines <8 mm long; several teeth with sharp concave grinding surfaces. ULGM 3496 nine spines <8 mm; one pelvic pterygiophore 4 mm. Kevin Meeks collection, UMMP 42391, 59 spines <7 mm; UMMP 42392, 205 teeth <3mm; 36 tooth fragments, 0.2–3 mm long, some with arch fragments. From matrix, four concave grinding teeth, ca. 1 mm long; pharyngeal arch with two sharp teeth and one broken tooth, 0.7 mm between tips of teeth. SDSM 86747, pelvic spines and teeth; SDSM 86761, pelvic spines: SDSM 86764, pelvic spines; UMMP 42385 left pelvic pterygiophore; UMMP 42386, unidentified arch and tooth?; UMMP 42387, unidentified teeth?

Comment.— Modern plagopterin species inhabit The Gila drainage and lower Colorado River drainage of southern Nevada, Utah, and Arizona, and restricted headwaters of the Little Colorado River, Arizona.

Catostomidae
Pantosteus hyomyzon
Fig. 10a, c

Pantosteus hyomyzon is an early Mountain Sucker known from Granger Clay Pit and the slightly older Juntura Formation (13.6–11.3 Ma) Smith, Stewart, Carpenter, 2013). The Sucker has short, angular dentaries (Fig.10) and the diagnostic dorsolateral crest above the opercular condyle of the hyomandibula (Smith et al., 2013, fig. 3a, d, e, f). The pharyngeal teeth are normally flat and pointed at the terminal corners. The figured specimen is abraded and similar to *Catostomus*.

Mountain Suckers and Dace, *Rhinichthys*, are characteristic inhabitants of the riffle zone where river slopes and currents
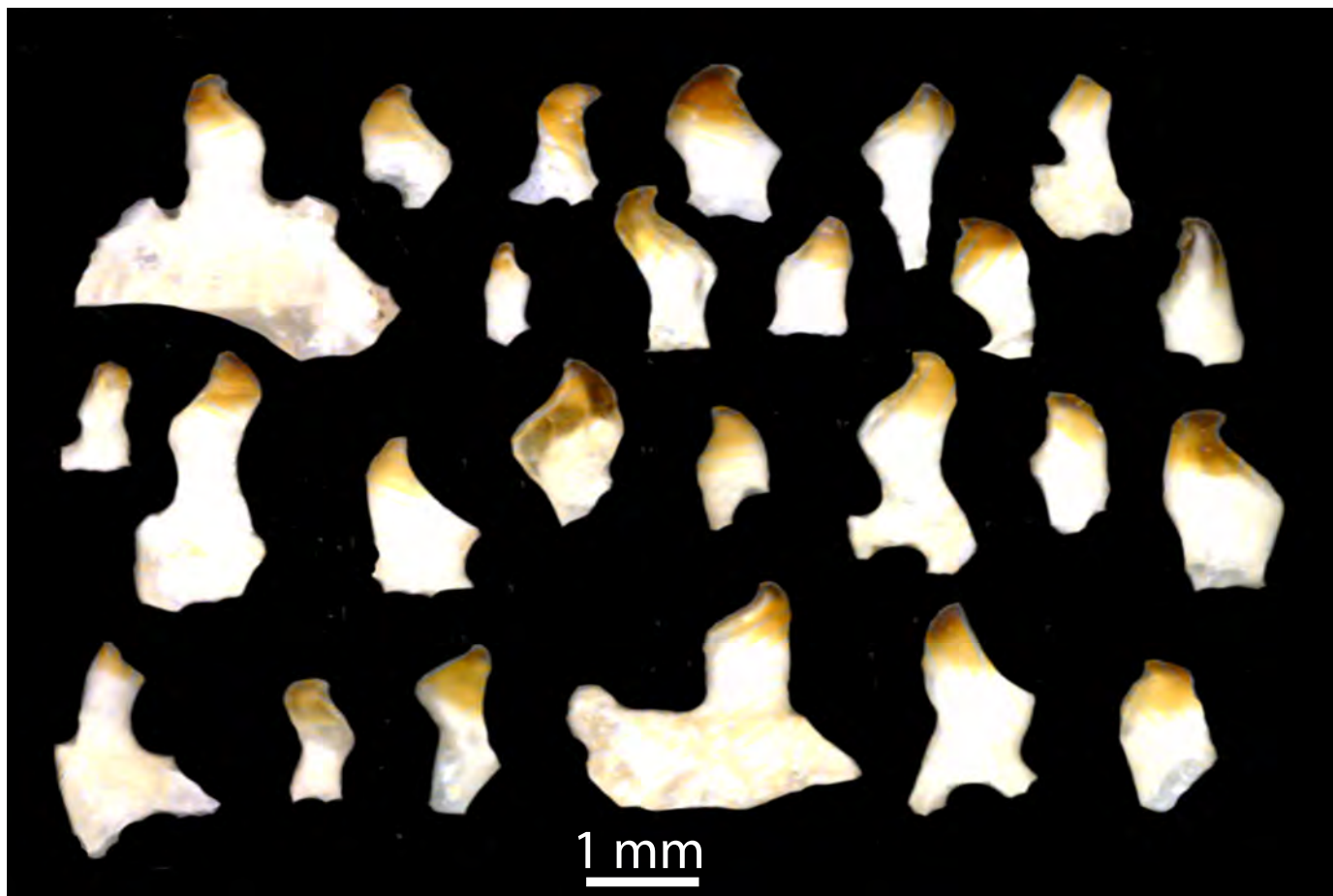
Figure 8.— Variation in teeth assigned to *Lepidomeda* with uncertainty (UMMP 42387).

are moderate in the foothills of Great Basin mountain ranges and the Colorado Plateau. They require a rubble substrate for spawning. Mountain Suckers now live in the Columbia, Snake, Colorado, and Rio Grande river headwaters, and the Bonneville, Lahontan, and Los Angeles basins, as well as restricted drainages in northern Mexico.

Centrarchidae
Archoplites sp.
Fig. 11

The *Archoplites* species of the Granger Clay Pit local fauna are the second smallest and most delicate individuals, next to those of the Bouse Formation in the Colorado River drainage near the Gulf of California (Reynolds et al., 2016). Its spines are sometimes intact, but its bones are always fragmented. The anal spines are strong and sharp, typical of the genus, but the dorsal spines are slender and at least sometimes have a distinct skirt oriented posteriorly, probably from alternate sides of the medial groove (Fig. 11c). Fragments of a preopercle and

lachrymal have small regularly-spaced serrations. The dentary (Fig. 11b) has small teeth in multiple rows and large sensory pore openings. The premaxilla (Fig. 11a) has small teeth in several rows.

The vertebrae (Fig. 11g) are slow-growing and small, even at age 6–9 (Fig. 11i), suggesting that the environment was not favorable for sunfish food items (insects and small crustaceans), perhaps because the stream was often choked with volcanic ash, with uncommon rubble substrate. The climate was inferred by Russell (1893) and paleobotanists to be milder than today. *Archoplites* and other centrarchids are warm-water fishes.

Archoplites now lives in the Great Valley of California, but in the late Miocene and Pliocene they ranged from the Ellensburg Formation to the Columbia and Snake basins, widespread parts of the Great Basin, and far south to the Bouse Formation, near the Gulf of California (Reynolds et al., 2016).

Material examined.— ULGM V3494, 20 spines <8.5 mm. ULGM V3498, partial maxilla, 13.5 mm. Meeks collection, UMMP 42393, 51 spines <9 mm, two lacrimals, 1 fragment of a premaxilla.
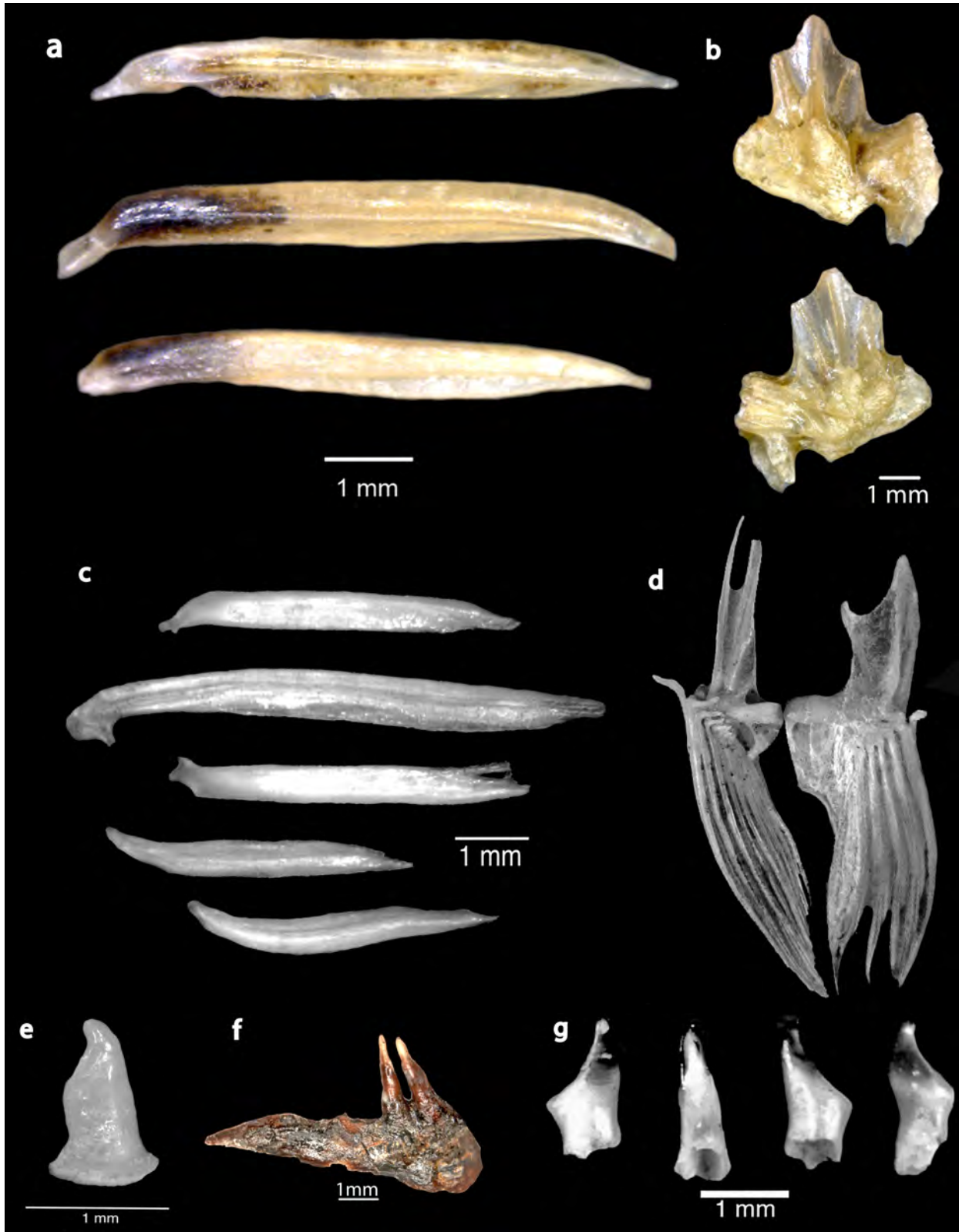
Figure 9.— Cf. *Lepidomeda.* **a,** three pelvic spines (SDSM 86761) from Granger Clay Pit; **b,** left pelvic pterygiophore (UMMP), dorsal and ventral view, from Granger Clay Pit; **c,** *Lepidomeda* pelvic spines (UMMZ 181747); **d,** pelvic fin pterygiophores and spines of recent *Rhinichthys* (UMMZ 173790) and *Lepidomeda* (UMMZ 181747); **e,** tooth of recent *Lepidomeda* (UMMZ 179572); **f,** unidentified arch and tooth, Granger Clay Pit (UMMP 42386); **g,** unidentified teeth (UMMP 42387), Granger Clay Pit.

Figure 10.— Catostomidae. **a,** dorsal condyle of *Pantosteus hyomyzon* (SDSM 86764), Granger Clay Pit; **b,** pharyngeal tooth of abraded *Pantosteus* or *Catostomus* sp. (SDSM 86764), lacking the diagnostic points on the corners of *Pantosteus* teeth, Granger Clay Pit*;* **c,** ventral and dorsal view of left dentary, *Pantosteus hyomyzon* (SDSM 86764), Granger Clay Pit.

DISCUSSION AND SUMMARY

The ~10.2 Ma fish assemblage collected by Kevin Meeks and James Martin from the Granger Clay Pit in the Ellensburg Formation of Yakima County, Washington provides a key sample of the development of fishes in the early Columbia River Basin and the Pacific Northwest. The paleofauna is the oldest assemblage of Neogene-modern Pacific-drainage fish diversity yet known from the state of Washington and the Columbia Basin. The fishes include an ancestor of *Ptychocheilus*, the Columbia pikeminnow. Other specimens, in the genera *Rhinichthys, Klamathella*(?)*, Mylocheilus, and Pantosteus* also continued through to be a part of the modern Columbia River fauna. The catfish, *Ameiurus*, no longer occurs

naturally in Western North America. The sunfish, *Archoplites,* is now endemic to the Sacramento River drainage, California. The Spine Dace, cf. *Lepidomeda,* is the most puzzling member of the paleofauna—its relatives are confined to the Lower Colorado drainage in Arizona, southern Nevada, and southern Utah (Miller and Hubbs, 1960). The plagopterine group has no other fossil record.

The subsequent fossil fish faunas in the area are the Taylor Flat (5–4.8 Ma) and Ringold (4.8–3 Ma) paleofaunas from 80 km to the east, near the southeastern bend in the Columbia River of Washington (Smith et al., 2000), with which the Granger Clay Pit shares four lineages. The nearby, older, fish faunas of note are the Drewsey (8.8–8.5 Ma) and Juntura (13.6–11.3 Ma) in the Drewsey-Juntura Basin, with which it shares four lineages. The Imbler (4.5–3.7 Ma) and Always Welcome Inn (4.5–4.4 Ma) paleofaunas (Van Tassel et al., 2001, 2007) of eastern Oregon also retain fish lineages much like those of the Granger Clay Pit local fauna. The shared lineages usually include *Ameiurus, Ptychocheilus, Mylocheilus,* and *Archoplites.*

The distribution of relatives of the Granger fish paleofauna suggests dispersal pathways from Columbia-Snake, Oregon-Idaho Graben, and upper Missouri River drainages. *Ptychocheilus* relatives may be in Japan; the oldest North American relatives include the specimen from Priest Rapids, Washington, and smaller individuals from Sucker Creek, in the Oregon-Idaho Graben in the mid Miocene. *Ameiurus* relatives are in eastern and southern North America, but ictalurid catfishes have been in western United States since the Eocene (Arce-H. et al., 2016). *Catostomus* and *Rhinichthys* are western North American genera with relatives in eastern North America; they have lived in the west for more than 10 m.y. (Carpenter and Smith, in press, this volume). *Archoplites* is currently the only western genus in the Centrarchidae. It lived in the west in the Late Miocene; it is first known in the Sucker Creek Formation in the Oregon-Idaho Graben (Carpenter and Smith, in press). *Mylocheilus* and *Archoplites* in the Miocene and Pliocene ranged from the Ellensburg Formation to the basal Bouse Formation near the mouth of the Colorado River. *Lepidomeda* and other Plagopterini are endemic to the Colorado River drainage in the Great Basin of Arizona, southern Nevada, and southern Utah; they have no fossil record except in the Granger Clay Pit. These Plagopterini are related to the non-spiny *Snyderichthys copei,* the Leatherside Chub (Miller and Hubbs, 1960), which once ranged as far north as the Wood River, Idaho, and with which Spinedace formerly hybridized.

A notable aspect of the Granger Clay Pit fish paleofauna is the complete absence of salmonids (salmon, trout, char, and whitefish), sculpins, and other coldwater fishes that became dominant in the modern fauna of the Columbia Basin in the Pleistocene. The Miocene abundance of warm-water catfish, sunfish, and southern minnows suggests low elevations, warm climate, and lack of a connection to the Pacific Ocean, except sporadically, as indicated by three bones of the giant salmon,
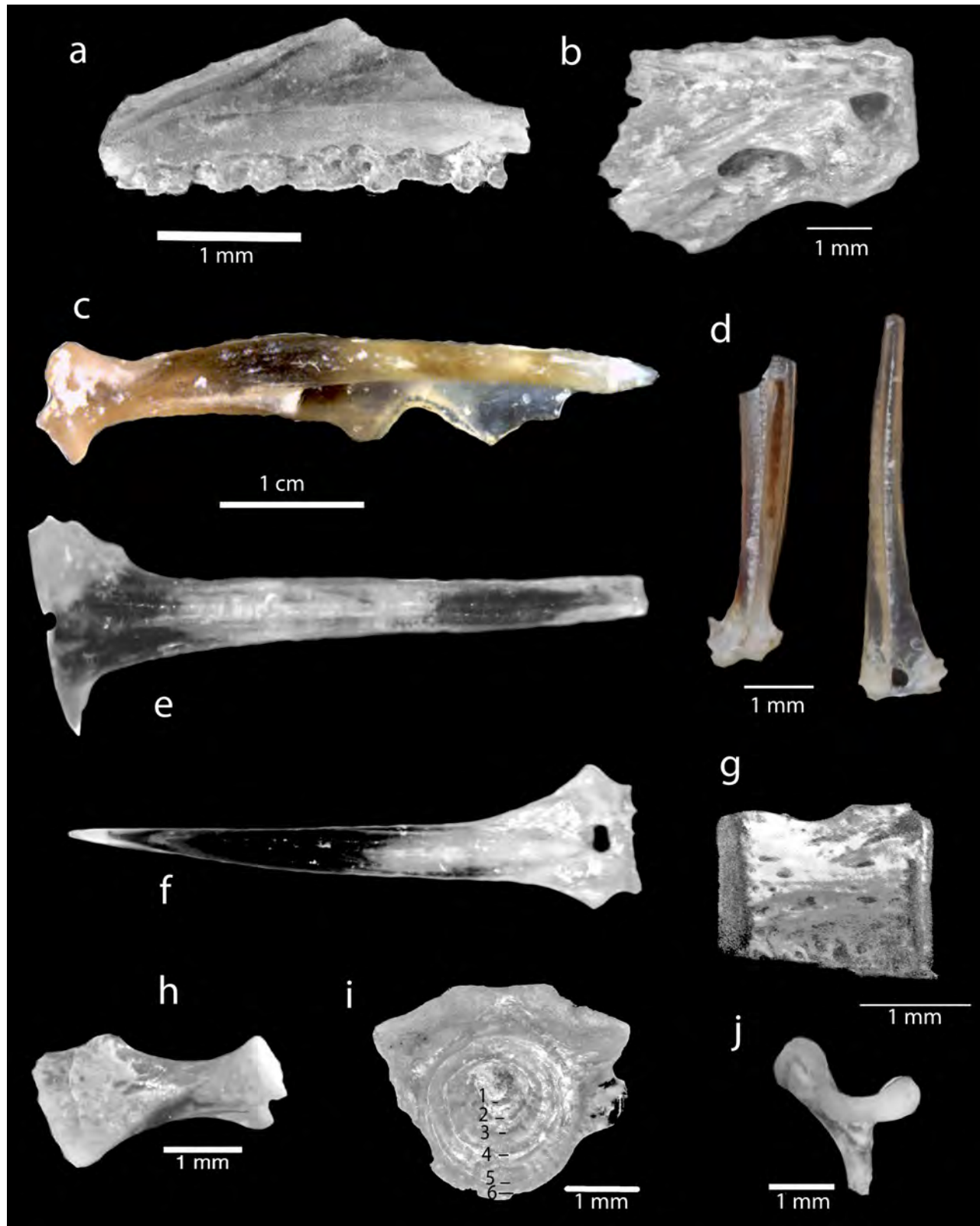
Figure 11.— *Archoplites* sp. **a,** right premaxilla (); **b,** right dentary (SDSM 86750); **c,** right mid-dorsal spine (SDSM 86760); **d,** dorsal spines (SDSM 86760); **e,** pelvic spine (SDSM 86760); **f,** anal spine (SDSM 86760; **g,** vertebra (SDSM 86754 part); **h,** ceratohyal (SDSM 86765 part); **i,** atlas showing annual growth rings (SDSM 86754 part); **j,** fragment of maxilla (SDSM 86765 part).

Oncorhynchus rastrosus, in the University of Washington Burke Museum (Smith et al., 2000).

The ca. 10.2 Ma age of the Granger Clay Pit fish paleofauna means that the widespread presence of *Ameiurus*, *Ptychocheilus, Pantosteus, Rhinichthys*, and *Archoplites* in faunas in the west is more ancient than previously thought. Each faunal element apparently has a separate biogeographical history, suggesting assembly of the fauna from diverse sources during a long history of volcanic disturbance in the basin of the Columbia Plateau.

There is no reason to suppose that these fishes dispersed into the Yakima drainage shortly before, or southward only after 10 Ma. It is possible that much or most of the northwestern North American fish fauna dispersed south earlier, possibly from the part of the continent that was later glaciated.

ACKNOWLEDGEMENTS

LITERATURE CITED

Arce-H., M., J. G. Lundberg, and M. A., O'Leary, 2016. Phylogeny of the North American catfish family Ictaluridae (Teleostei: Siluriformes) combining morphology, genes and fossils. Cladistics, 33(4): 406–428.

Baskin, J. A. 1998. Mustelidae, in C. M. Janis, K. M. Scott, and L. L. Jacobs (eds.), Evolution of Tertiary Mammals of North America Volume 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals. Cambridge University Press: 152–173.

Beck, G. F. 1938. [Report on fossils from Ellensburg Formation]. Central Washington College Geological Bulletin, 4(2): 1p.

Beck, G. F. 1945. Ancient forest trees of the sagebrush area in central Washington. Journal of Forestry, 43(5): 334–338.

Beck, G. F. 1946. Fauna and Flora of the Tyrrell Quarry, Selah, Washington. Geological Society of the Oregon Country Bulletin, 12(6): 46.

Black, C. C. 1963. A review of the North American Tertiary Sciuridae. Harvard Museum of Comparative Zoology Bulletin, 130(3): 109–248.

Bryant, L. J. 1968. A new genus of mustelid from the Ellensburg Formation, Washington: Los Angeles County Museum Contributions in Science, 139: 6 pp.

Chappell, W. M., J. W. Durham, and D. E. Savage. 1951. Mold of a rhinoceros in basalt, lower Grand Coulee, Washington. Geological Society of America Bulletin, 62(8): 907–918.

Edwards, S. W. 1976. A mandible of *Beckia* (Mammalia: Mustelidae) from Contra Costa County, California. PaleoBios, 20(1): 6 pp.

Evarts, R. C., J. E. O'Conner, R. E. Wells, and I. P. Madin. 2009. The Portland Basin: A (big) river runs through it. Geology, 19(9): 4–10.

Evernden, J. F. and G. T. James. 1964. Potassium-argon dates and the Tertiary floras of North America. American Journal of Science, 262(8): 945–974.

Farooqui, S. M., J. D. Beaulieu, R. C. Bunker, D. E. Stensland, and R. E. Thomas, 1981. Dalles Group: Neogene formations overlying the Columbia River basalt Group in north-central Oregon. Oregon Geology, 43(10): 131–140.

Foxworthy, B. L. 1962. Geology and ground-water resources of the Ahtanum Valley, Yakima County, Washington. USGS Water-Supply Paper, 1598: 100 pp.

Gustafson, E. P. 1978. The vertebrate faunas of the Pliocene Ringold Formation, South-Central Washington. University of Oregon Museum of Natural History Bulletin, 23: 62pp.

Gustafson, E. P. and J. Eaton. 1983. Type specimens at the University of Oregon: Fossil Vertebrates and Plants. University of Oregon Museum of Natural History Bulletin, 24: 11 pp.

Harrison, J. A. 1985. Giant camels from the Cenozoic of North America. Smithsonian Contributions to Paleobiology, 57: 1–29.

Honey, J. G., J. A. Harrison, D. R. Prothero, and M. S. Stevens. 1998. Camelidae, in C. M. Janis, K. M. Scott, and L. L. Jacobs (eds.) Evolution of Tertiary Mammals of North America Volume 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals. Cambridge University Press, pp. 439–462.

Hubbs, C. L. and C. W. Hibbard. 1951. *Ictalurus lambda*, a new catfish, based on a pectoral spine from the Lower Pliocene of Kansas. Copeia, 1951(1): 8–14.

Kelly, T. S. 1992. New middle Miocene camels from the Caliente Formation, Cuyama Valley Badlands, California. PaleoBios, 13(52): 1-22.

Lambert, W. D. and J. Shoshani. 1998. Proboscidea, in C. M. Janis, K. M. Scott, and L. L. Jacobs (eds.), Evolution of

Tertiary Mammals of North America Volume 1: Terrestrial Carnivores, Ungulates, and Ungulate–like Mammals. Cambridge University Press: 606–621.

Lindsey, K. A. 1996. The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-central Washington and North-central Oregon. Washington Division of Geology and Earth Resources Open File Report, 96–8: 45 pp.

Lucas, S. G. and G. S. Morgan. 2008. Taxonomy of *Rhynchotherium* (Mammalia, Proboscidea) from the Miocene-Pliocene of North America. New Mexico Museum of Natural History and Science Bulletin, 44: 71–87.

Madin, I.P., 2009, Portland, Oregon, geology by tram, train, and foot: Oregon Geology, 69(1): 73–92.

Martin, J. E., 2014. A Clarendonian occurrence of the fossil insectivore, *Plesiosorex* (Mammalia), from Washington. South Dakota Academy of Science Proceedings, 93: 55–59.

Martin, J. E. and A. R. Tedrow. 1988. Two carnivores from the Ellensburg Formation (Miocene) of central Washington. South Dakota Academy of Science Proceedings, 67: 80–83.

Martin, J. E. and D. C. Pagnac. 2009. A Vertebrate Assemblage from the Miocene Rattlesnake Ridge member of the Ellensburg formation, central Washington, in Albright, L. B. III (ed.), Papers on Geology, Vertebrate Paleontology, and Biostratigraphy in Honor of Michael O. Woodburne. Museum of Northern Arizona Bulletin, 65: 197–216.

Martin, J. E. and V. S. Mallory. 2011. Vertebrate Paleontology of the Late Miocene (Hemphillian) Wilbur Locality of Central Washington. Paludicola, 8(3): 155–185.

MacFadden, B. J. 1984. Systematics and phylogeny of *Hipparion, Neohipparion, Nannipus,* and *Cormohipparion* (Mammalia, Equidae) from the Miocene and Pliocene of the New World. American Museum of Natural History Bulletin, 179: 196 pp.

McKee, E. H., D. A. Swanson and T. L. Wright. 1977. Duration and volume of Columbia River Basalt volcanism, Washington, Oregon, and Idaho. GSA Abstracts with Programs (Cordilleran Section), 9: 463–464.

Merriam, J. C. 1915. New species of the *Hipparion* group from the Pacific coast and Great Basin provinces of North America. University of California Publications in Geological Sciences, 9(1): 1–8.

Merriam, J. C. 1916. Mammalian remains from a late Tertiary formation at Ironside, Oregon. University of California Publications Bulletin of the Department of Geology, 10(9): 129–135.

Merriam, J. C. and J. P. Buwalda. 1917. Age of strata referred to the Ellensburg formation in the White Bluffs of the Columbia River. University of California Publications Bulletin of the Department of Geological Sciences, 10(15): 255–266.

Merriam, J. C., C. Stock, and C. L. Moody. 1925. The Pliocene Rattlesnake Formation and fauna of eastern Oregon with notes on the geology of the Rattlesnake and Mascall

deposits. Carnegie Institution of Washington Publication, Contributions to Paleontology, 347(3): 43–92.

Miller, R. R., and C.L. Hubbs, 1960. The Spiny-rayed Cyprinid Fishes (Plagopterini) of the Colorado River System. University of Michigan Museum of Zoology, Miscellaneous Publication, 115: 38 pp. 3 pl.

Orcutt, J. D., and S. S. Hopkins. 2011. The canid fauna of the Juntura Formation (late Clarendonian), Oregon. Journal of Vertebrate Paleontology, 31(3): 700–706.

Osborn, H. F. 1936, Proboscidea. A monograph of the discovery, evolution, migration and extinction of the mastodonts and elephants of the world. New York, American Museum Press, 802 pp.

Pigg, K. B. and W. C. Wehr. 2002. Tertiary flowers, fruits, and seeds of Washington State and adjacent areas – Part III. Washington Geology, 30(3/4): 3–16.

Prothero, D. R. 2005. The evolution of North American Rhinoceroses. Cambridge University Press, 224 pp.

Reynolds, R E., M. A. Roeder, T. A. Wake, and G. R. Smith, 2016. Freshwater fauna and flora from Bouse basal marl in Little Chemehuevi Wash. Desert Symposium, 2016, pp. 112–120.

Russell, I. C. 1893. A geological reconnaissance in central Washington. USGS Bulletin, 108: 108.

Russell, I. C. 1900. A preliminary paper on the geology of the Cascade Mountains in northern Washington. USGS Annual Report, 20(2): 89–210.

Schmincke, H.-U. 1964. Petrology, paleocurrents, and stratigraphy of the Ellensburg Formation and interbedded Yakima Basalt flows, south-central Washington. Johns Hopkins University Ph.D. Dissertation: 426 pp.

Shotwell, J. A. 1961. Late Tertiary biogeography of horses in the northern Great Basin. Journal of Paleontology, 35(1): 203–217.

Smiley, C. J. 1963. The Ellensburg flora of Washington. University of California Publications in Geological Sciences, 35(3): 159–276.

Smith, G. A. 1988a. Neogene synvolcanic and syntectonic sedimentation in central Washington. GSA Bulletin, 100(9): 1479–1492.

Smith, G. A. 1988b. Sedimentology of proximal to distal volcaniclastics dispersed across an active fold belt, Ellensburg Formation (late Miocene), central Washington. Sedimentology, 35(6): 953–977.

Smith, G. A. and N. P. Campbell. 1989. Geochronology of the Ellensburg Formation – Constraints of Neogene Volcanism and Stratigraphic Relationships in Central Washington. Isochron/West, 53: 28–32.

Smith, G.R., and R.R. Miller. 1985. Taxonomy of fishes from Miocene Clarkia lake beds, Idaho, pp. 75–84 *in* C.J. Smiley (Ed.), Late Cenozoic History of the Pacific North West. A.A.A.S. Pacific Div., San Francisco, 417 pp.

Smith, G. R., J. D. Stewart and N. E. Carpenter. 2013. Fossil and Recent Mountain Suckers, *Pantosteus*, and significance

of introgression in catostomine fishes of western United States. University of Michigan Museum of Zoology Occasional Papers, 743: 1–59.

Smith, G. R., N. Morgan, and E. P. Gustafson. 2000. Fish of the Mio-Pliocene Ringold Formation, Washington: Pliocene capture of the Snake River by the Columbia River. University of Michigan Papers on Paleontology, 32: 47 pp.

Smith, G.R., T. Dowling, K.W. Gobalet, T. Lugaski, D. Shiazawa, and R.P. Evans. 2002. Biogeography and timing of evolutionary events among Great Basin fishes, pp. 175–234, *in* R. Hershler, D.B. Madsen, and D.R. Currey, Great Basin Aquatic Systems History. Smithsonian Contributions to Earth Sciences, Number 33, 405 pp.

Tedford, R.H., L.B. Albright, III, A.D. Barnosky, I. Ferrusquia-Villafranca, R.M. Hunt, Jr., J.E. Storer, C.C. Swisher, III, M.R. Voorhies, S.D. Webb, and D.P. Whistler. 2004. Mammalian biochronology of the Arikareean through Hemphillian interval (late Oligocene through early Pliocene epochs). Pp. 169–231 *In* M.O. Woodburne (ed.), Late Cretaceous and Cenozoic Mammals of North America—Biostratigraphy and Geochronology. Columbia University Press.

Tedford, R. W., T. Galusha, M. F. Skinner, B. E. Taylor, R. W. Fields, J. R. Macdonald, J. M. Rensberger, S. D. Webb, and D. P. Whistler. 1987. Faunal succession and biochronology of the Arikareean through Hemphillian interval (late Oligocene through earliest Pliocene epochs) in North America. *In* M. O. Woodburne (ed.), Cenozoic Mammals of North America: Geochronology and Biostratigraphy, 153–210.

Van Tassel, J., M. Ferns, V. McConnell, G. R. Smith. 2001. The Imbler fish fossils, Grande Ronde Valley, NE Oregon and the Pliocene Lake Idaho-Columbia River connection. Oregon Geology, 63(3): 77–96.

Van Tassel, J., and 16 co-authors, 2007. Early Pliocene (Blancan) Always Welcome Inn local fauna, Baker City, Oregon. Oregon Geology, 68: 3–23.

Wallace, R. L., and D. W. Zaroban. 2013. Native Fishes of Idaho. American Fisheries Society, Bethesda, Maryland.

Wang, X., R. H. Tedford, and B. E. Taylor. 1999. Phylogenetic systematics of the Borophaginae (Carnivora: Canidae). American Museum of Natural History Bulletin, 243: 391 pp.

Warren, W. C. 1941. Relation of Yakima Basalt to the Keechelus Andesitic Series. Journal of Geology, 49(8): 795–814.

Whistler, D. P., R. H. Tedford, G. T. Takeuchi, X. Wang, Z. J. Tseng, and M. E. Perkins. 2009. Revised Miocene biostratigraphy and biochronology of the Dove Spring Formation, Mojave Desert, California. Museum of Northern Arizona Bulletin, 65: 331–362.

Wilson, M. V. H. 1996. The Eocene fishes of Republic, Washington. Washington Geology, 24(2): 30–31.

Woodburne, M. O. 1996, Reappraisal of the *Cormohipparion* from the Valentine Formation, Nebraska: American Museum Novitates, 3163: 1–56.

Woodburne, M. O. 2007. Phyletic diversification of the *Cormohipparion occidentale* complex (Mammalia; Perissodactyla, Equidae), late Miocene, North America, and the origin of the old world Hippotherium datum: American Museum of Natural History Bulletin, 306: 138p.