Fish Biostratigraphy of Late Miocene to Pleistocene Sediments of the Western Snake River Plain, Idaho

by

Gerald R. Smith[1], Krystyna Swirydczuk[2], Peter G. Kimmel[3], and Bruce H. Wilkinson[1]

ABSTRACT

The Chalk Hills and Glenns Ferry Formations represent a large lacustrine system with peripheral and capping fluvial and floodplain facies. Both formations are bounded by unconformities. They are separated by at least 1 million years at exposures along the south flank of the Snake River Plain, but were possibly continuous some place in the basin.

The Chalk Hills Formation is late Miocene (about 8.5 to 5.5 million years). Fish fossils define three biostratigraphic zones: (1) An upper zone immediately above and below the lower Horse Hill ash layer is characterized by the presence of *Mylocheilus inflexus* and *M. copei* (two large minnows with molar teeth) and *Hucho larsoni* (a large troutlike fish). (2) A middle zone, well below the lower Horse Hill ash layer and above the Hot Spring limestone, is characterized by the presence of *Mylopharodon doliolus* (a primitive minnow) and *Orthodon onkognathus* (a herbivorous minnow), as well as the three species in the upper zone. (3) A lower zone, presently known only from Brown Creek in Owyhee County, is characterized by the salmonlike fish, *Smilodonichthys*, as well as the five species in the upper and middle zones.

The Pliocene Glenns Ferry Formation lacks the six species listed above; it is characterized by the presence of *Prosopium prolixus* (a whitefish), *Mylocheilus robustus* (a minnow with molar teeth), and *Kerocottus divaricatus* (an endemic sculpin). Middle and upper zones within the Glenns Ferry Formation are defined by a reduction in the tooth formula of *Mylocheilus robustus* and the addition of four species of sculpins. The upper zone, defined by the presence of *Kerocottus pontifex* and *hypoceras* (spiny sculpins) and *Myoxocephalus antiquus* and *idahoensis* (northern sculpins), possessed the richest fish fauna (24 species) known in ancient or Holocene western North America.

Most lake beds studied are transgressive, beach-shoreface sands and offshore silts of the Glenns Ferry Formation. They are capped by a regressive sequence exposed at about 3,400 feet along the southern basin margin and at about 2,900 feet near the center of the basin. Floodplain silts with a distinct Pliocene fish assemblage are exposed from 2,900 feet to 3,300 feet at the Hagerman Cliffs. Pleistocene floodplain deposits are exposed at about 2,700 feet in the center of the basin. Following drainage of the lake, possibly through the Pleistocene capture at Hells Canyon, about half of the fish species became extinct.

INTRODUCTION

...the entire basin, from the Rocky Mountains to the Blue Mountains of Oregon, was a freshwater lake, on whose bottom was deposited a curious succession of sand and clay beds....At the exposures of these rocks in the cañon-walls of the present drainage system are found ample evidences of the kind of life which flourished in the lake itself and lived upon its borders. Savage fishes, of the garpike type [trouts], *and vast numbers of cyprinoids, together with mollusks, are among the prominent water-fossils....From being a wide and beautiful expanse of water, edged by winding mountain shores, with forest-clad slopes containing a fauna whose remains are now charming those light-minded fellows, the paleontologists, the scene has entirely changed, and a monotonous, blank desert now spreads itself as far as the eye can reach.*

Clarence King (1903, p. 229)
on the Snake River Plain

Clarence King (1878) recognized that the late Cenozoic history of the western United States was domi-

[1]Museum of Paleontology and Department of Geological Sciences, University of Michigan, Ann Arbor, Michigan 48109.
[2]Exploration Research Division, Conoco, Inc., Ponca City, Oklahoma 74601.
[3]Department of Chemistry, George Mason University, Fairfax, Virginia 22030.

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nated by a vast lacustrine system with climate, life, and geological processes markedly different from those of today. E. D. Cope (1870, 1883a, 1883b) distinguished separate, smaller lakes and assigned Pliocene and Pleistocene ages to some of them, primarily on the basis of fossil fishes collected by J. C. Schenk of King's Survey of the 40th Parallel and by Cope's collectors, Charles Sternberg and J. L. Wortman. The question that attracted King and Cope is still of interest: What were the environments and processes responsible for the late Cenozoic freshwater deposits of the Snake River Plain? After 100 years of research the answers are still interconnected with the evolutionary history of the associated fishes.

In this paper we describe several sedimentary units in the western Snake River Plain and discuss their stratigraphy and environments of deposition as illuminated by fossil fishes. Our purpose is to describe the distribution and variation of fishes that occupied the western Snake River Plain during the late Miocene, Pliocene, and early Pleistocene. Fishes are the most common macroscopic fossils in these lake beds, and they provide a stratigraphic biozonation as well as new information about environment and climate.

Malde and Powers (1962) provided the most complete description of the stratigraphy of the Snake River Plain. They classified sedimentary and volcanic rocks of Miocene to Pleistocene series into seven formations of the Idaho Group, and they documented the history of stratigraphic understanding from Cope's "Lake Idaho" to their conception, which is used here.

We are especially interested in the four major units containing lake deposits exposed south of the Snake River from southeastern Oregon to Hagerman, Idaho. These are, from oldest to youngest: (1) the Poison Creek Formation of late Miocene age—mostly fluvial deposits generally south and west of Murphy, Owyhee County, Idaho, unconformably deposited on the Miocene Idavada Volcanics; (2) the Chalk Hills Formation—lacustrine and fluvial deposits of late Miocene age unconformably deposited on Idavada rocks south of Grand View and Bruneau in Owyhee County; (3) the Glenns Ferry Formation—lacustrine, fluvial, and floodplain sediments of Pliocene age, unconformably deposited on the Chalk Hills Formation or on basalts over the whole length of the western Snake River Plain; and (4) the Bruneau Formation—middle Pleistocene lake beds and basalts resting on the Glenns Ferry Formation from Hagerman to Murphy, Idaho. All four formations dip toward the axis of the basin. The lake beds of the Bruneau Formation and the fluvial deposits of the Poison Creek Formation contain a few fish fossils, and we have little to add to the account of Malde and Powers. The sediments of the Chalk Hills and Glenns Ferry Formations, especially the lacustrine silts and fine, shoreface sands south of Grand View and Bruneau, are superficially similar. They contain distinctive ash beds and fossil fishes and are bounded by unconformities that allow some clarification, but their stratigraphic relations are complicated in many places.

We focus on the Chalk Hills and Glenns Ferry Formations because the two lakes in which they were deposited were the site of evolution of the most diverse fish fauna in late Cenozoic western North America (Smith, 1981). The fishes permit biostratigraphic zonation consistent with the recognized rock stratigraphy. The resulting correlations are comparable with those based on volcanic ashes (Swirydczuk and others, 1982 this volume) and suggest extensions of stratigraphy to surrounding areas.

PALEONTOLOGICAL BACKGROUND

Paleontological contributions to stratigraphy of the Idaho Group are based primarily on mammalian and molluscan remains, summarized by Malde and Powers (1962), Taylor (1966), Zakrzewski (1969), Shotwell (1970), Bjork (1970), and Neville and others (1979). The major difficulty with paleontological evidence has been the inability to distinguish between temporal and environmental changes in faunal composition.

The Poison Creek Formation, best exposed in Reynolds Creek, has produced few fossils. It consists of fine-grained terrigenous clastics and siliceous volcanic ash deposits. The fauna, including horse teeth (*Hipparion*) identified by Buwalda (1924) and Shotwell (in Malde and Powers, 1962) and an otter, in the absence of the horse *Pliohippus*, is correlated with the Clarendonian Juntura and Deer Butte Formations of southeast Oregon (Shotwell, 1963, p. 28). The overlying Banbury Basalt is in turn overlain by Chalk Hills Formation, which contains a basalt dated by Armstrong and others (1975) as at least 8.4 million years old. The Chalk Hills Formation contains fluvial sands and lacustrine sands and silts that yielded beaver (*Dipoides*), rhinoceros, camel, horse (*Hipparion*), sloth (*Megalonyx*), and a molluscan fauna that indicate a Hemphillian age (Malde and Powers, 1962; Armstrong and others, 1975). Fission-track dates on volcanic ashes indicate sedimentation until about 5 or 6 million years ago (Kimmel, 1982 this volume).

The Glenns Ferry Formation has produced molluscs and at least two large Blancan mammalian faunas of broad stratigraphic significance. The late Pliocene age of these fossils was clearly indicated by molluscan evidence (Taylor *in* Malde and Powers, 1962; Taylor, 1966). Unfortunately, several sources of confusion led to a Pleistocene interpretation of the mammalian evidence, prior to clarification through potassium-argon dates of 3.5, 3.3, and 3.2 million years on the Deer Gulch lava flow and two ashes at Hagerman (Evernden and others, 1964), a fission-track date of 3.75 ± .36 million years on zircon from the Peters Gulch Ash Bed (Izett, 1981), and thorough mammalian paleontology by Zakrzewski (1969) and Bjork (1970), working with Claude W. Hibbard.

The lack of laterally continuous beds has prevented an understanding of the relationship of the Hagerman sequence (over 100 fossil localities) to localities at Sand Point (across the Snake River from Hammett), Jackass Butte (west of Grand View), and the lake beds south of Grand View and Bruneau. Hibbard and Zakrzewski (1967) presented evidence, in the form of variation in dental characters of mice referred to *Ophiomys*, that the Sand Point fauna is younger than the Hagerman and that the Grand View local fauna is still younger. Although Shotwell (1970) argued that these faunas could be the same age because differences among them might have been environmental, Zakrzewski (1969) and Bjork (1970) showed that the Hagerman local fauna was early Blancan and Pliocene and that the Grand View local fauna was latest Blancan and early Pleistocene. Correlation of mammalian and magnetic stratigraphy by Neville and others (1979) verified this, placing the Hagerman fauna correlative to the Gilbert reversed and Gauss normal epochs, and the Sand Point and Grand View faunas correlative to the Matuyama reversed epoch. Bjork (1970, p. 13) placed the Sand Point fauna nearer the Hagerman fauna. The Blancan chronology by Neville and others (1979) is in accord with that usually accepted, differing from that of Armstrong and others (1975), in suggesting younger dates for the Glenns Ferry Formation and the Blancan.

Interpretation of the above relationships was advanced by Malde's (1972) measured sections and facies interpretations. Malde recorded extensive fluvial deposits in addition to the floodplain and lacustrine sediments. However, we interpret some of the fluvial sands as nearshore lacustrine sands, partly on the basis of fish paleontological evidence.

The major sedimentary units referred to in the following are (1) transgressive shoreface sands and offshore silts of the Chalk Hills Formation, and (2) transgressive shoreface sands and offshore silts overlain by regressive sands and floodplain silts of the Glenns Ferry Formation. The floodplain deposits at Hagerman probably span much of the time represented by the Glenns Ferry Formation. Upper Glenns Ferry floodplain deposits extend westward in local outcrops across the entire study area. The transgressive beach deposits, however, including major phosphatic, oolitic, and conglomeratic systems, seem to progress eastward and southward, marking the expansion of the Glenns Ferry lake. Regressive sands, overlain by poorly sorted silts, are found capping lake deposits from Shoofly Creek to Castle Creek. The Chalk Hills and Glenns Ferry sands that we interpret as shoreface sand deposits have produced the most abundant and diverse fish collections; the Glenns Ferry floodplain deposits produce a mixture of fishes and other vertebrates.

FISH PALEONTOLOGY

Fishes have been collected from 190 localities in the Chalk Hills and Glenns Ferry Formations between Hagerman, Idaho, and Adrian, Oregon (Figure 1). Of 35,000 specimens, mostly bone fragments picked from the ground surface, 14,000 have been classified. Thirty-nine kinds of fishes are recognized. Some have limited range, defining stratigraphic zones; others indicate lacustrine or fluvial habitat preference. Our method of analysis has been to compare vertical distributions of kinds of fishes from section to section, testing potential zone limits with lateral correlation based on ashes and other sedimentological markers. Comparisons of fish occurrences with sediment characteristics and the presence or absence of mammalian fossils led to hypotheses about environments of deposition. These hypotheses are tested by their internal consistency relative to the general sedimentological model and evolutionary patterns here described.

The fishes are members of six families common to the late Cenozoic of North America (Smith, 1981). These include whitefish, trouts, and salmon (family Salmonidae) in the genera *Prosopium*, *Rhabdofario*, *Hucho*, *Oncorhynchus*, *Smilodonichthys*, and perhaps *Salmo*. The most abundant remains are from the suckers (family Catostomidae), strictly freshwater fishes represented by *Chasmistes*, of zoogeographic importance (Taylor, 1960; Miller and Smith, 1981) and *Catostomus*, which has at least five species in the system. The most diverse family is the Cyprinidae (minnows), a strictly freshwater group which gained access to North America from northeast Asia probably in the Oligocene and which shows its earliest and most extreme western American diversification in the Miocene and Pliocene lakes described here. The genera are *Acrocheilus* and *Orthodon*, large herbivores; *Ptychocheilus*, a large carnivore; *Mylocheilus*, a group of molluscivores; *Idadon*, a small herbivore; *Mylopharodon*, a medium-sized molluscivore (?) that preferred fluvial habitats; and *Gila* and *Richardsonius*, medium- and small-sized generalists. The fourth

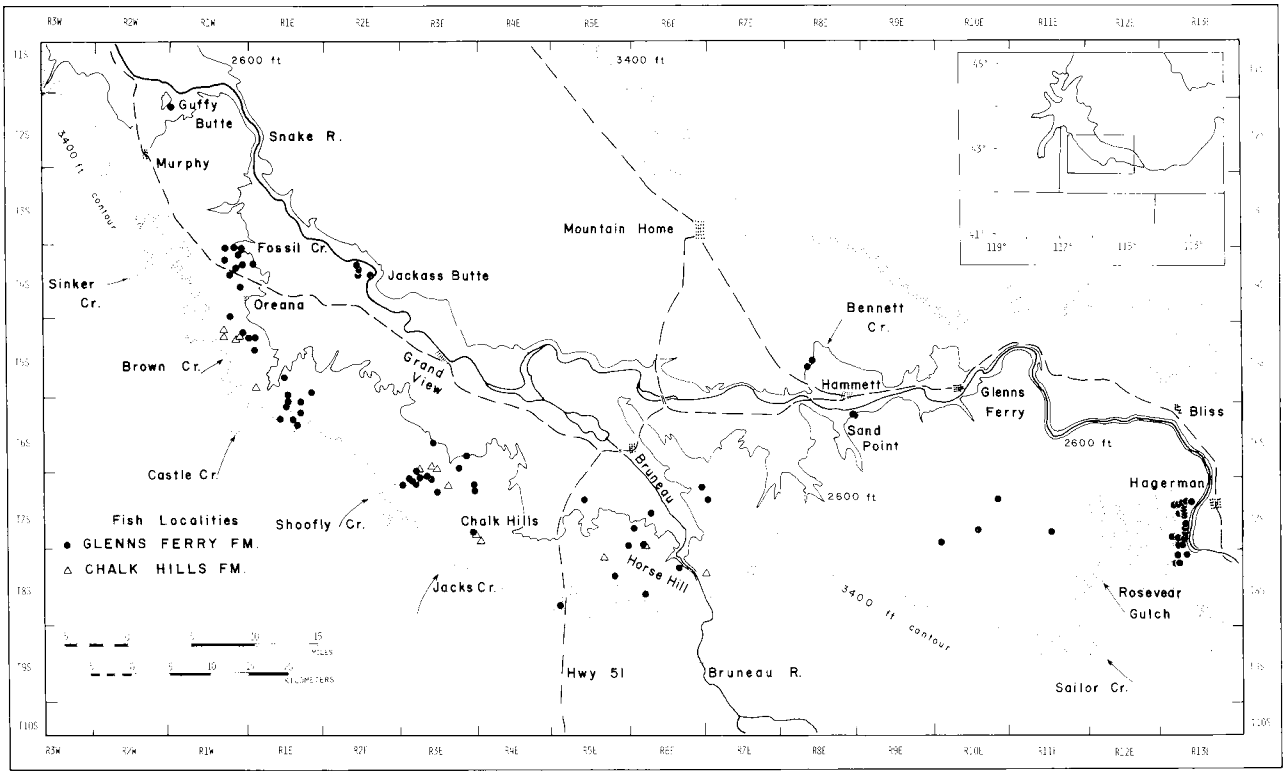

Figure 1. The western Snake River Plain. ● Glenns Ferry fish localities; Δ Chalk Hills fish localities.

diverse group in the fauna includes small benthic sculpins of the family Cottidae. These are represented by the arctic and subarctic relict genus *Myoxocephalus*, the endemic lacustrine genus *Kerocottus*, and the widespread genus *Cottus*. The fauna also contains abundant catfish (*Ictalurus*, Ictaluridae) and sunfish (*Archoplites*, Centrarchidae), common to lakes and streams. In the accounts below we stress forms with stratigraphic or environmental significance. Additional descriptions, illustrations, and taxonomic analyses were presented by Smith (1975) and Kimmel (1975).

Fish localities are listed in Table 1, which also gives the recorded occurrences of each species.

FAMILY SALMONIDAE, TROUTS

Subfamily Coregoninae, Whitefishes

Prosopium prolixus Smith (Figure 3A, B, C). This large whitefish is a reliable indicator of the Glenns Ferry Formation. It has not been found below the unconformity at the base of the formation. *Prosopium* is uncommon in the Hagerman floodplain silts and absent from the Grand View local fauna. A Holocene species, *Prosopium williamsoni*, inhabits the Snake River, but continuity is not implied. The two species are different in the relative lengths of the facial bones—*prolixus* being a unique, large-mouthed species and *williamsoni* being small-mouthed and more typical of *Prosopium*.

The genus is northern or high-elevation in North America and Siberia, being restricted to relatively cold waters. Its appearance, simultaneously with the distributionally similar Cottidae, indicates immigration from the north facilitated by a cooling climate between Chalk Hills and Glenns Ferry time. The long, simple, toothless jaws are easily identified stratigraphic indicators.

Subfamily Salmoninae, Trouts

Smilodonichthys Cavender and Miller (Figure 2A, B). This genus is based on a large salmonlike fish from the Miocene (Barstovian-Hemphillian) of Oregon and California. On the Snake River Plain it is known only from the lowest levels of the Chalk Hills Formation, as exposed in Brown Creek. The presence of this form and the distinct *Mylopharodon* from the same level indicates that these beds are older than other Chalk Hills sediments. The enlarged conical teeth, at the end of otherwise nearly toothless jaws, are unique and unmistakable indicators.

Oncorhynchus salax Smith. This species was attributed to the Glenns Ferry Formation by Smith (1975, p. 11), but reevaluation of the type locality at Shoofly Creek shows that the fine-grained concretion in which it is found is from Chalk Hills lake beds. *Oncorhynchus* has been found at a number of localities in the Chalk Hills and Glenns Ferry Formations, and no stratigraphic value has been discovered.

Rhabdofario carinatum Kimmel (Figure 2F, G, H). This species was described from what we now recognize as Chalk Hills sediments southwest of the Snake River in Malheur County, Oregon (Kimmel, 1975, p. 73). It has since been collected from numerous localities in the Chalk Hills Formation of Idaho. Compared with its Glenns Ferry counterpart, *R. lacustris*, the maxilla is somewhat salmonlike, with a low-angled premaxillary process that is broadly connected to the tooth-bearing part of the bone. The maxillary teeth are evenly graded in size. The dentaries develop less expanded exostosis near the symphysis.

Rhabdofario lacustris Cope (Figure 2C, D, E). This species is restricted to the Glenns Ferry Formation. Compared with *R. carinatum*, the premaxillary process of *Rhabdofario lacustris* is spatulate with a longitudinal groove under the anteromesial edge. It is proximally restricted and normally projects at a greater angle. The maxillary teeth are abruptly smaller on the posterior half of the bone. Many large specimens show bony expansion near the dentary symphysis.

Relationships of this genus are uncertain. It is found in Pliocene sediments at Honey Lake, Lassen County, California (Taylor and Smith, 1981), and a similar form is known from Pliocene sediments in the Chappala Formation, north of Lake Chappala, Mexico. Near the top of the Glenns Ferry lake beds, at Fossil Creek and Bennett Creek, it becomes uncommon, being partially replaced by smaller trout much more like *Salmo*. Whether they are part of the same lineage is not known.

Hucho larsoni (Kimmel) (Figure 2I, J, K). This species was described in the genus *Paleolox* from Chalk Hills sediments southwest of the Snake River in Oregon. It shares several characteristics with *Hucho perryi* of Asia, including a transverse row of teeth at the anterior end of the prevomer, the strong retroarticular notch in the angular, and an elevated premaxillary process of the maxilla. Some features are similar to *Salvelinus*; the premaxilla is identical to that of *Salvelinus confluentus* Cavender. Except for several specimens, one with several associated parts, reported from Horse Hill by Smith (1975, p. 18), this species is restricted to the Chalk Hills Formation. Some of the Horse Hill specimens collected first could have been from below the unconformity before it was recognized; some are weathered and are possibly from reworked concretions. Otherwise, the species seems to be a useful Chalk Hills indicator. It is especially abundant in lower Chalk Hills sediments. Maxillae and angulars are common and easily identified (Figure 2I, J).

Unidentified salmonids. Several additional kinds of salmonids are present in the Glenns Ferry Formation, but specimens are fragmentary or of uncertain taxonomic allocation (see account of *Rhabdofario lacustris* above). The most distinctive form, possibly *Salmo*, is represented by flat maxillae with minute teeth, from the Horse Hill beach deposits (Smith, 1975, Figure 4D).

FAMILY CATOSTOMIDAE, SUCKERS

Chasmistes spatulifer Miller and Smith (Figure 3D, E). This species is an abundant and useful indicator of the Glenns Ferry Formation and possibly the Bruneau Formation. A similar form has been collected in four older samples (see below). The elongate jaw bones are diagnostic, and their abundance in Glenns Ferry shoreface sands is often helpful to biostratigraphy in the field. The genus is also found in Pliocene to Holocene lakes in the Great Basin (Miller and Smith, 1981).

Chasmistes sp. (Miller and Smith, Figure 11D, J). Specimens related to the previous species but with shorter, less attenuate jaw bones are found in four Chalk Hills(?) samples and in many Glenns Ferry samples. The specimens from the Bruneau Formation are tentatively referred to this category. The oldest known *Chasmistes* is from Sand Hollow, 6 miles west of Vale, Oregon, sec. 33, T. 19 S., R. 44 E. Except for the *Chasmistes* the specimens appear to be a Chalk Hills equivalent, with *Mylocheilus inflexus*. The other fishes present are *Acrocheilus latus*, *Ptychocheilus arciferus*, *Orthodon onkognathus*, *Idadon*, *Catostomus* sp., *Ictalurus peregrinus*, and *Archoplites taylori*. Specimens of *Chasmistes* sp. have also been collected from the Chalk Hills Formation at Parker Ranch and from two localities 2 miles southwest of Horse Hill. The last three occurrences are possibly lag contaminants from the overlying Glenns Ferry beds, but they are too numerous and too similar to dismiss. Related forms were native to the upper Snake River drainage and Fossil Lake, Oregon (Miller and Smith, 1981).

Catostomus (*Deltistes*) *owyhee* (Miller and Smith). This distinctive, highly specialized species is present at nearly all Glenns Ferry sites except the Grand View local fauna and equivalents. It is rare in floodplain sediments, but abundant in what we interpret as lake beds. A more generalized form of what is clearly the same lineage is common in Chalk Hills samples, but the differences are slight. Maxillae, dentaries, and skulls are described and figured by Miller and Smith

Table 1. Locality information for the samples that form this report, with presence of fish species indicated by X.

	NUMBER OF SAMPLES	TOWNSHIP	RANGE	SECTION	ELEVATION (feet)	*Smilodonichthys sp.	*Hucho larsoni	Rhabdofario carinatum	Ictalurus peregrinus	*Orthodon onkognathus	*Mylopharodon doliolus	*Mylocheilus inflexus	*Mylocheilus copei	*Mylocheilus robustus (early)	*Mylocheilus robustus (late)	Chasmistes sp.	*Chasmistes spatulifer	*Prosopium prolixus	*Cottus bairdi	*Kerocottus divaricatus	*Kerocottus hypoceras	*Kerocottus ponifex	*Myoxocephalus idahoensis	*Catostomus macrocheilus	*Catostomus cristatus	Catostomus shoshonensis	Catostomus owyhee	Catostomus arenatus	Orthodon hadrognathus	Idadon condonianus	Idadon hibbardi	Mylopharodon hagermanensis	Gila milleri	Richardsonius durranti	Ptychocheilus arciferus	Acrocheilus latus	Ictalurus vespertinus	Archoplites taylori	Archoplites sp.	Myoxocephalus antiquus	Cottus calcatus	Rhabdofario lacustris	Oncorhynchus spp.	Salmonidae unidentified
PLEISTOCENE																																												
Bruneau Formation	2	(T3S, R1E, S21 & T7S, R5E, S36)				.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.
Grand View local fauna	7	4S	2E	9,15,16	2525-2600	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	X	.	.	.	X	.	.	.	X	X	.	X	X	X	.	.	.	.	.	.	.
Guffy Butte	1	2S	2W	NE12	2700	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	X	X	X	.	.	.	.	.	.
PLIOCENE																																												
UPPER GLENNS FERRY FORMATION																																												
Bennett Creek	2	5S	8E	SW16	2730	.	.	.	.	.	.	.	.	.	X	X	.	X	.	X	X	X	X	X	.	X	X	X	X	.	X	X	X	X	X	X	X	X	?	.	.	X	.	X
Sand Point	3	6S	8E	SW1	2600-2690	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	X	X	?	X	X	X	X	X	.	X	X	X	.	X	X	X	X	X	.	.	X	X	.
Shoofly regressive beach	2	7S	3E	5,6	3317	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	X	.	X	X	X	.	X	.	X	.	.	.	X	X	X	X	.	.	.	X	.	.
Birch Creek regressive beach	1	6S	1E	NW2	3244	.	.	.	.	.	.	.	.	.	X	X	X	X	.	X	X	X	X	.	X	X	X	.	X	.	X	X	.	.	X	X	X	X	.	.	.	X	.	.
Castle Creek regressive beach	1	6S	1E	NW3	3322	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	X	X	.	X	X	X	.	.	.	X	.	.	.	X	X	.	X	.	.	.	.	.	.
Crayfish Hill (Fossil Creek)	7	4S	1W	SW1	2825-2875	.	.	.	.	.	.	.	.	.	X	X	X	X	.	X	X	X	X	.	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	.	.	X	X	.
GLENNS FERRY FINE SANDS																																												
Henderson Creek	2	4S	1E	7	2875	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	X	.	X	X	X	X	X	.	X	.	X	X	X	X	X	X	X	.	.	X	.	X
Lower Fossil Creek	2	4S	1W	11,12	2940,2875	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	X	.	.	X	X	.	X	X	X	.	.	.	X	X	X	X	.	.	.	X	.	X
Fossil Creek roadcut	7	4S	1W	11,14	3010	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	X	X	?	X	X	X	.	X	X	X	.	X	.	X	X	X	X	X	X	X	X	X	X
Picket Creek	1	4S	1W	24	2970	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	X	.	.	X	X	.	X	X	X	X	.	.	X	X	.	X	.	.	.	X	.	X
Rosevear Gulch	1	7S	10E	SW12	2975	.	.	.	.	.	.	.	.	.	X	.	X	.	.	X	.	.	.	.	.	.	X	.	.	X	.	.	X	.	X	X	X	X	.	.	.	.	.	.
Twenty-mile Gulch	1	6S	3E	SW32	3130	.	.	.	.	.	.	.	.	.	X	.	X	.	.	X	.	.	.	.	X	X	X	.	.	X	X	.	.	.	X	X	.	X	.	.	.	X	.	.
6 miles E Horse Hill	1	7S	6E	NW25	3210	.	.	.	.	.	.	.	.	.	X	.	X	X	.	.	.	X	.	.	X	.	X	.	X	.	.	.	.	.	X	X	X	X	.	.	.	X	.	.
HORSE HILL BEACH																																												
6 miles E Horse Hill	1	7S	6E	NW25	3200	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	X	.	.	X	.	X	.	.	X	.	.	.	.	X	X	.	X	.	.	.	X	.	.
3 miles NE Horse Hill	1	7S	6E	17,20	2720	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	.
4 miles NE Horse Hill	1	7S	6E	NW21	2825	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.
4 miles E Horse Hill	1	7S	6E	SW33	3010	.	.	.	.	.	.	.	.	.	X	X	.	X	.	X	.	.	.	.	X	X	X	X	.	X	.	.	.	.	X	X	X	X	.	.	.	X	.	.
North side Horse Hill	6	7S	5E	35,36	3025	.	r	.	.	.	.	r	.	.	X	.	X	X	.	X	.	X	.	.	X	X	X	.	X	X	X	.	X	.	X	X	X	X	X	.	X	X	X	X
5 miles NW Horse Hill	1	7S	5E	SW9	2800	.	.	.	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	X
3 miles S Horse Hill	1	8S	3E	11,14	3225	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	X	.	.	X	X	.	.	.	X	X	X	X	.	.	.	.	.	.
5 miles SE Horse Hill	1	8S	6E	NW20	3250	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	X	.	.	.	X	.	X	.	X	X	X	X	.	.	.	X	.	.
7 miles SE Horse Hill	1	8S	6E	29	3320	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	.	X	.	X	.	X	.	.	.	X	X	X	X	.	.	.	X	.	.
Highway 51 roadcut	2	8S	5E	30	3400	.	.	.	.	.	.	.	.	.	X	.	.	X	.	X	.	.	.	.	.	X	X	.	.	X	X	.	.	.	X	X	X	X	.	.	X	X	.	X
Dove Spring	1	7S	10E	NE31	3100	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	.	.	.	.	X	X	.	.	X	X	X	X	.	.	.	.	.	.
SANDS ABOVE OOLITE																																												
Shoofly	3	7S	3E	5,6	3150	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	X	.	X	.	X	.	.	.	X	X	X	X	.	.	.	.	.	.
Castle Creek	1	5S	1E	SW34	3200	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	X	.	.	.	X	.	.	.	X	X	.	X	.	.	.	.	.	.
Brown Creek	1	5S	1E	NW7	2975	.	.	.	.	.	.	.	.	.	X	.	.	X	.	X	.	.	.	.	.	X	X	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.
Hart Creek	1	4S	1W	33	3400	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	.	.	.	.	X	X	X	.	X	.	X	.	.	.	X	X	.	X	.	.	.	.	.	.
Blackjack Butte, Oregon	1	22S	46E	8,18	3200,3320	.	.	.	.	.	.	.	.	.	?	.	X	X	.	X	.	.	.	.	X	X	X	.	X	X	.	.	.	.	X	X	X	X	.	.	.	X	.	.
Shoofly between limonites	3	6S	3E	35	2975	.	.	.	.	.	.	.	.	.	?	.	X	X	.	X	.	.	.	.	X	.	X	.	.	X	X	.	.	.	X	.	X	X	.	.	.	X	.	.
Birch Creek between oolites	4	6S	1E	NE15	3475	.	.	.	.	.	.	.	.	.	?	.	X	X	.	X	.	.	.	.	X	X	X	.	.	X	X	.	.	.	X	X	X	X	.	.	.	X	X	.
Castle Creek between oolites	3	6S	1E	SE9	3500	.	.	.	.	.	.	.	.	.	?	.	X	X	.	X	.	.	.	.	X	X	X	.	.	.	X	.	.	.	X	X	X	X	.	.	.	X	.	.

Table 1. continued

Locality	NUMBER OF SAMPLES	TOWNSHIP	RANGE	SECTION	ELEVATION (feet)	*Smilodonichthys sp.	*Hucho larsoni	Rhabdofario carinatum	Ictalurus peregrinus	*Orthodon onkognathus	*Mylopharodon doliolus	*Mylocheilus inflexus	*Mylocheilus copei	*Mylocheilus robustus (early)	*Mylocheilus robustus (late)	Chasmistes sp.	*Chasmistes spatulifer	*Prosopium prolixus	*Cottus bairdi	*Kerocottus divaricatus	*Kerocottus hypoceras	*Kerocottus pontifex	*Myoxocephalus idahoensis	*Catostomus macrocheilus	*Catostomus cristatus	Catostomus shoshonensis	Catostomus owyhee	Catostomus arenatus	Orthodon hadrognathus	Idadon condonianus	Idadon hibbardi	Mylopharodon hagermanensis	Gila milleri	Richardsonius durranti	Ptychocheilus arciferus	Acrocheilus latus	Ictalurus vespertinus	Archoplites taylori	Archoplites sp.	Myoxocephalus antiquus	Cottus calcatus	Rhabdofario lacustris	Oncorhynchus spp.	Salmonidae unidentified
GLENNS FERRY BASAL SANDS																																												
Ag Lime Butte (Shoofly Creek)	2	7S	3E	NE9	3150									X				X								X	X				X				X	X		X				X		
Shoofly	4	7S	3E	4-6	3025-3250							r		X			X	X							X	X	X		X	X	X	X			X	X	X	X				X	X	
Birch Creek	2	6S	1E	10,11	3310-3400									X												X	X								X	X								
Castle Creek	2	5,6S	1E	3,28	3000-3175									X												X	X								X		X							
Brown Creek	4	5S	1E 1W	(12), (12,18)	2850-3150							r		X		X		X		X			X		X	X	X	X	X	X	X				X	X	X	X				X	X	
Parker Ranch (Jacks Creek)	2	7S	3E	NE36	3125									X			X	X		X					X	X	X				X				X	X	X	X			X	X		
NE Shoofly	1	6S	3E	35	2975									X			X			X					X		X				X				X							X		
Davis Ranch (Shoofly Creek)	2	6S	3E	SW25	2840									X			X	X		X					X	X	X			X	X				X	X	X	X				X	X	X
Sand Pits (Shoofly Creek)	4	6S	3E	21	2800									X			X	X		X		X				X	X	X	X	X	X	X			X	X	X	X				X		
Hagerman cliffs, 2,900-3,500 feet	96	7S 8S	13E 13E	16,17,20,21,28,29,32 4,5,8										X			X	X						?		X	X	X	X		?	X	X		X	X	X	X				?		X
CHALK HILLS FORMATION (MIOCENE)																																												
2 miles E Horse Hill	1	7S	6E	NE31	3025		X		X			X	X												?	?	?		X		?	?			X	X		X					X	
2 miles SW Horse Hill	1	8S	5E	NW11	3150		X	X	X			X	X			?											?								X			X			?			
2 miles SW Horse Hill	1	8S	5E	SW3	3060		X	X	X			X				X										?					?	?			X	X		X						
Parker Ranch (Jacks Creek)	2	7S	3E	25,36	3080,3105			?	X			X				X									?	?	?	?				?	?		X	X		X					X	
Twenty-mile Gulch	1	6S	3E	32	3060			?	X			X	X												?	?	?			X		?			X	X		X						
Shoofly	2	6S	3E	33	2990				X			X	X												?	?	?		X	?		?			X	X		X					X	X
NE Shoofly	1	6S	3E	35	2935				X			X														?									X			X						
Ag Lime Butte (Shoofly Creek)	1	7S	3E	3	3050			?	X			X	X													?						?			X	X		X					X	X
East of Bruneau River	1	8S	7E	SW7	3120				X			X													?	?						?			X			X						X
OREGON, MALHEUR COUNTY, NEAR ADRIAN																																												
Schenk Ranch	2	22S	46E	36	2750			X	X			X	X																X	X					X	X		X						
Tunnel Road	4	22S	46E	15,16	2500-2600		X	X	X	X		X	X												?	?			X	X					X	X		X						X
Tunnel Mountain	3	22S	46E	22	2640-2720		X	X	X	X		X	X												?	?	?		X	?					X	X		X		?	X			X
Redrock	3	22S	46E	SE21	2540-2700			X	X			X	X												?					X					X	X		X						X
MIDDLE CHALK HILLS FORMATION, IDAHO																																												
Upper Castle Creek	1	5S	1E	NE31	3290				X			X													?						?	?				X		X						X
2 miles E Horse Hill	3	7S	6E	NE31	3005			?	X	X	X	X	?							c					?	?				X					X	X		X					X	
LOWER CHALK HILLS FORMATION, IDAHO																																												
Brown Creek	3	5S	1W	2	3040	X	X	X	X		X	X	X												?	?									X	X		X						

*=zone-defining form; X=present; r=reworked; c=contamination from above; ?=precise identification uncertain. Horse Hill localities are measured from the bench mark at the northwest corner of section 36, at the north side of Horse Hill.

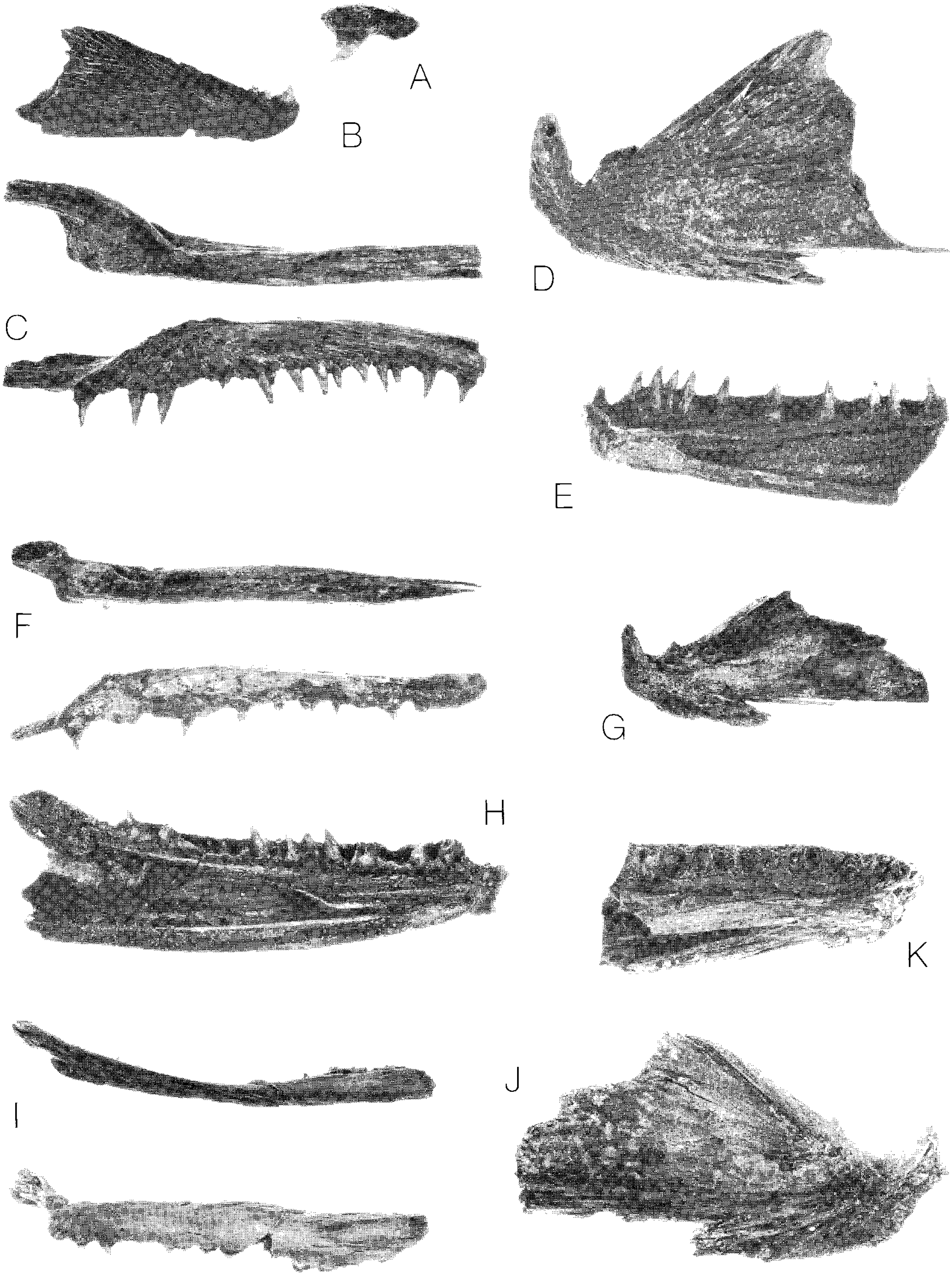

Figure 2. Diagnostic trout. (A,B) Premaxilla and dentary of *Smilodonichthys* sp., zone indicator for the lower Chalk Hills Formation, X¾ (C,D,E) Maxilla, angular, and dentary of *Rhabdofario lacustris* of the Glenns Ferry Formation, X1 (F,G,H) Maxilla, angular, and dentary of *Rhabdofario carinatum* of the Chalk Hills Formation, X¾ (I,J,K) Maxilla, angular, and dentary of *Hucho larsoni* of the Chalk Hills Formation.

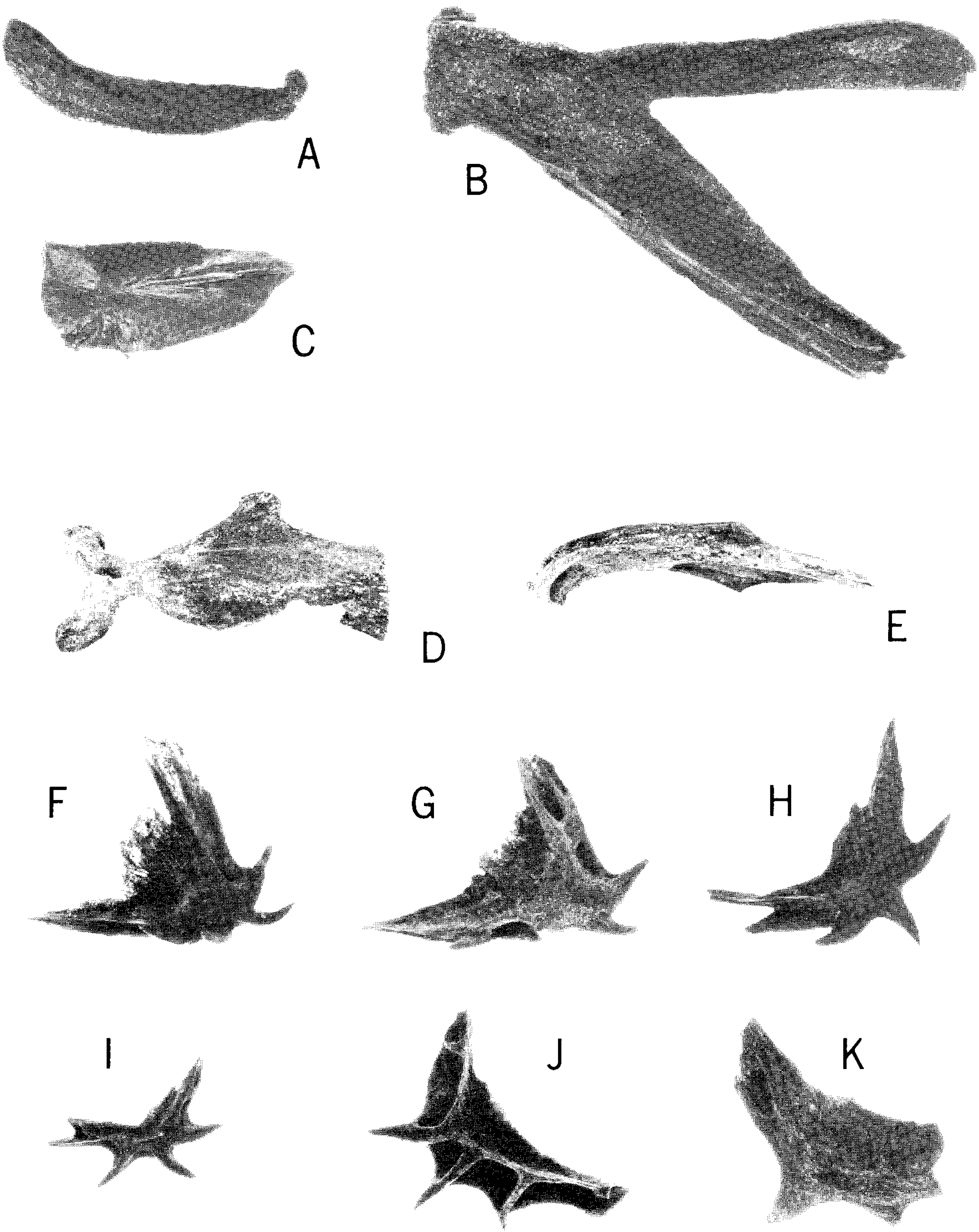

Figure 3. (A,B,C) Maxilla, dentary, and frontal of *Prosopium prolixus*, zone indicator for the Pliocene part of the Glenns Ferry Formation, X½. Chasmistes spatulifer, (D) Maxilla, (E) dentary, X½. Preopercles of sculpins, Cottidae, of the Glenns Ferry Formation, X2. (F) *Kerocottus divaricatus*, (G) *Kerocottus pontifex*, (H) *Kerocottus hypoceras*, (I) *Myoxocephalus antiquus*, (J) *Myoxocephalus idahoensis*, (K) *Cottus calcatus*.

(1967, Figures 3, 4A), and Smith (1975, Figures 10E, 11B-G, 12B, F, K).

Catostomus (*Deltistes*) *shoshonensis* Cope. This name is based on a skull, but records listed here are based on maxillae of the "*ellipticus*" form (Miller and Smith, 1967, Figure 4C; Smith, 1975, Figure 12A). Dentaries attributed to *cristatus* by Smith (1975, Figure 12C) might actually belong with *shoshonensis* maxillae. Dentaries thought to be associated with this species by Smith (1975, Figure 12D, E, J) might be *owyhee*. In the Glenns Ferry Formation, this species is distinct, at least on the basis of maxillae; in the Chalk Hills Formation, the differences between this and the following form are difficult to demonstrate. The species is absent from Grand View sediments.

Catostomus (*Catostomus*) *cristatus* Cope. This name is based on a skull, but records listed here are based on maxillae (Smith, 1975, Figure 12G, and probably I). The species is distinct in the Glenns Ferry Formation, except that maxillae and dentaries grade into forms similar to *Catostomus macrocheilus*, especially near the top of the formation. In the Chalk Hills samples, maxillae of this species are most abundant, but difficult to separate from *shoshonensis*. In floodplain sediments this is the most abundant sucker.

Catostomus (*Pantosteus*) *arenatus* Miller and Smith (1967, Figure 5B, C). This species is rare in the study area, especially in lake beds, and of no known significance as a stratigraphic indicator.

FAMILY CYPRINIDAE, MINNOWS

The most abundant fossils of the family Cyprinidae are pharyngeal arches—the only tooth-bearing bones they possess. The teeth show differentiation in size, shape, number, and arrangement. In the genus *Mylocheilus* evolutionary changes in teeth permit stratigraphic zonation.

Mylocheilus inflexus (Cope) (Figure 4A). This species is based on specimens collected by J. L. Wortman near Sinker Creek, but the type locality has not been relocated. *Mylocheilus inflexus* has been taken at all Chalk Hills fish localities. It is the most reliable indicator of the Chalk Hills Formation, except that abraded specimens are occasionally found reworked in the basal one meter of the Glenns Ferry Formation. Because of its distinctive shape and exceptional durability, it is a useful zone marker in the field. The arches are asymmetrical, most having five teeth on the left arch and four (occasionally three or five) on the right. Tooth sockets for missing teeth are easily recognized. Teeth of the left and right arches worked side-by-side in the fish, grinding upward against the basioccipital process of the skull. These details are stratigraphically helpful, because they are the basis for distinguishing between *Mylocheilus inflexus* and its sister species described below.

Mylocheilus copei Smith and Kimmel new species (Figure 4B, C). A second species of *Mylocheilus* is found with *inflexus* in the Chalk Hills Formation. It is restricted to the Chalk Hills Formation as far as is known, and is therefore reliable as a zone indicator, but not so easy to use because of its similarity to the Glenns Ferry species, *Mylocheilus robustus*. *Mylocheilus copei* is described here to make the name available, but will be redescribed in more detail in a later report.

Description. The holotype, UMMP 62681 (Figure 4B), is a left pharyngeal arch with two associated cleithra, one opercle, and the basioccipital collected by Peter Kimmel from the Chalk Hills Formation in Malheur County, Oregon, sec. 22, T. 22 S., R. 46 E., elevation 2,640 feet. The arch has a maximum length of 32 millimeters. The tooth row is 18 millimeters long, with five teeth in the major row, the first being only slightly smaller than the second, and two relatively large teeth in the minor row. Orientation of the major row enabled the teeth of the two arches to grind in opposition, rather than against the basioccipital as in most minnows. The anterior limb is 12 millimeters long and deflected into a face that articulates with the opposite arch; the posterodorsal limb is 16 millimeters long. The teeth range from subconical (minor row and tooth 5 of major row) to molariform (teeth 1, 2, 3, and 4). Tooth counts of several large samples from the type locality and elsewhere in the Chalk Hills Formation show that the major rows of the left and right arches have five teeth with few exceptions; minor rows almost invariably have two teeth (Table 2; Figure 5). There is no ontogenetic loss of teeth.

Diagnosis. A cyprinid fish with smooth molariform pharyngeal teeth. There are five teeth in the major row; two in the minor. The species differs from *Mylopharodon* in having more flattened molariform teeth and a shorter posterodorsal limb on the arch. Pharyngeal arches of *copei* differ from *Mylocheilus inflexus* in having a minor row of teeth, modally five teeth on the right, and a short posterodorsal limb. *M. copei* differs from *robustus* in the maintenance of the tooth formula throughout life (Figure 5) and in the large molariform first tooth of the major row and stronger teeth in the minor row. *Mylocheilus caurinus* has the first tooth of the major row larger than the second and normally has a single tooth in the minor row.

Etymology. For Edward Drinker Cope.

Mylocheilus robustus (Leidy) (Figure 5). This species is limited to the Glenns Ferry Formation below the level of the Grand View local fauna on the Snake River Plain. What appears to be the same

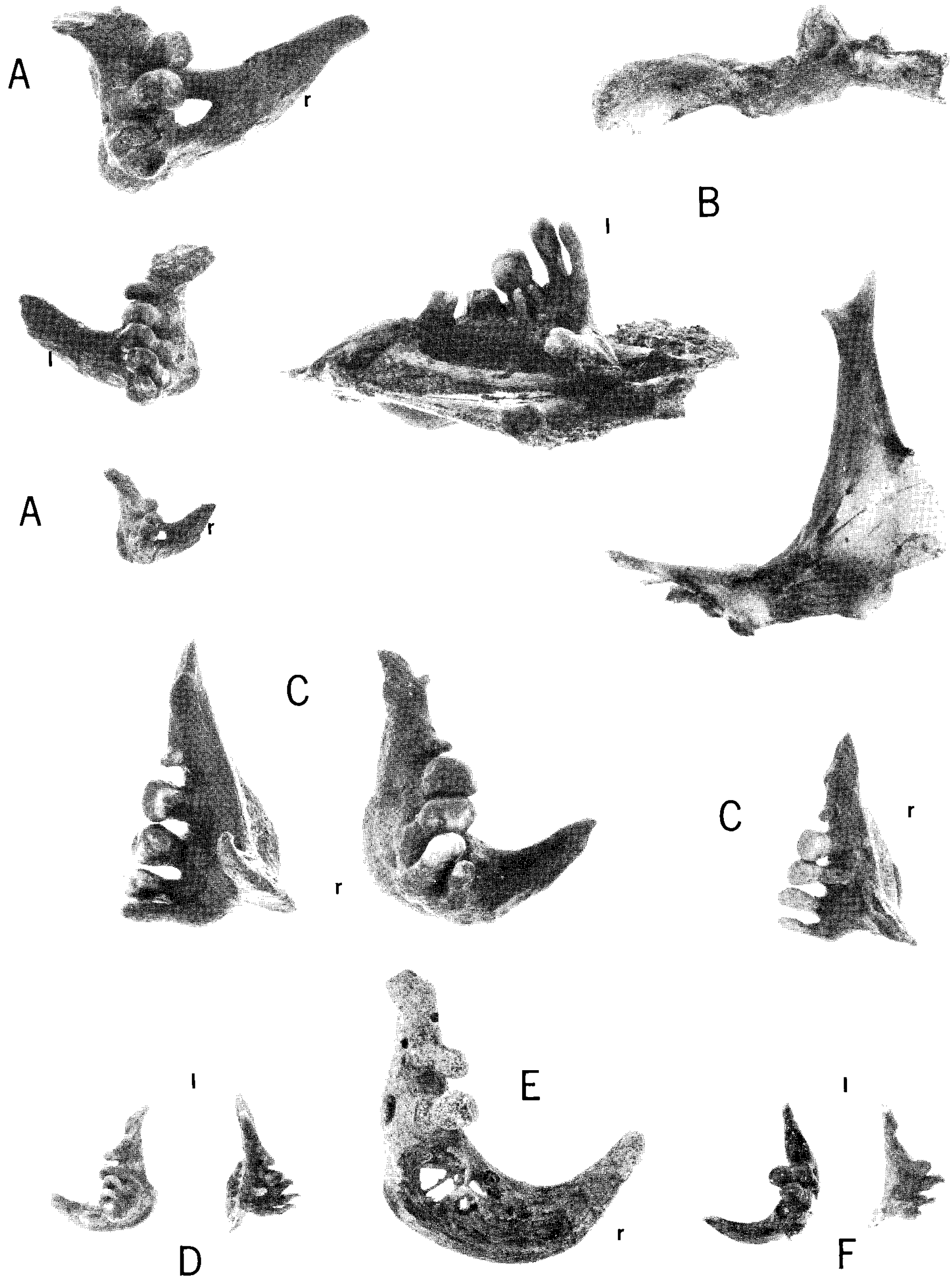

Figure 4. (A) Graded size series of pharyngeal arches of *Mylocheilus inflexus* of the Chalk Hills Formation, showing change in shape. L (left), R (right). (B) Holotype of *Mylocheilus copei* of the Chalk Hills Formation (UMMP 62681), left pharyngeal arch, basioccipital, cleithrum (associated). (C) Pharyngeal arches of *Mylocheilus copei*. (D) *Mylopharodon hagermanensis*. (E) Holotype of *Mylopharodon doliolus* Smith and Kimmel, new species, from the lower Chalk Hills Formation at Horse Hill (UMMP 74197). (F) *Mylocheilus doliolus* from the lower Chalk Hills Formation at Brown Creek. All bones X½.

species has been collected from Idaho Group sediments (coarse sands) near Idaho City in the Boise River drainage (UMMP 31901, washed out of a mining claim 200 feet below the surface). *Mylocheilus inflexus* and *robustus* are reported from the Cache Valley Formation in northern Utah by McClellan (1977). The group will prove to have broader stratigraphic significance when its range is better known.

On the Snake River Plain variation in *robustus* permits stratigraphic zonation. The morphological change through the Glenns Ferry Formation is expressed as a reduction in teeth. The first sign of reduction is loss of the anterior tooth on the right arch of large individuals. Evidently selective pressure for fewer, larger teeth led to increasingly early tooth replacement and reduction (seen as increased frequency of arches with four rather than five major teeth in progressively smaller individuals as we go higher in the section). Reduction in teeth in the minor row follows a similar pattern. In basal Glenns Ferry sands, small fish have a tooth formula of 2,5-5,2 (2 left minor, 5 left major, 5 right major, 2 right minor). Small fish are defined as having no teeth larger than 4 millimeters in diameter; the largest tooth in the middle-sized fish is between 4 and 8 millimeters in diameter. Middle-sized *robustus* in the basal sands usually have 2,5-[4 or 5],2; large fish usually have 2,5-4,2 (Table 2; Figures 5A-C, 6).In the latest lake beds, for example at the old railroad grade at Bennett Creek in Elmore County, small fish usually have 1,5-4,1; middle-sized fish usually have 1,[4 or 5]-4, [0 or 1]; the larger fish have 1,4-4,1 with some variation

Table 2. Variation in numbers of pharyngeal teeth in the major $_{(M)}$ and minor $_{(m)}$ rows in *Mylocheilus copei* and *robustus*, as a function of size. (N) sample size.

Locality		Left$_m$	N	Left$_M$	N	Right$_M$	N	Right$_m$	N
M. robustus (late phenotypes)									
Bennett Creek	large	-	-	-	-	4	1	1	1
	medium	.9	25	4.4	25	4	11	.6	14
	small	1	4	5	8	4	4	1	5
Fossil Creek roadcut	large	1	3	4	4	4.1	9	.2	9
	medium	.9	7	4.8	9	4.3	4	2	2
	small	1.4	5	5	7	4	3	1	4
Fossil Creek (lower)	large	1	18	4.5	14	4	15	.6	11
	medium	1	6	4.8	5	4.7	5	1.3	4
	small	1.7	5	5	3	-	-	-	-
Crayfish Hill	large	0	4	4.1	7	4	4	-	-
	medium	1	4	4.6	8	4	11	1	9
	small	1.3	3	4.8	5	4.7	3	1	2
Horse Hill	large	1.2	16	4.3	15	4.1	19	1.1	19
	medium	1.6	33	4.8	34	4.2	43	1.4	41
	small	2	1	5	2	4.3	3	1.5	4
Deerwater Spring	large	1	3	5	1	4	1	-	-
	medium	1	1	5	1	4	1	1.5	2
	small	1	1	5	2	-	-	2	1
Hot Creek (2 miles SE of Horse Hill)	large	2	1	4	1	4.5	2	2	3
	medium	1.7	4	4.5	4	4	9	1.5	10
	small	-	-	-	-	4	1	1	1
Rosevear Gulch	large	-	-	4	1	4.5	4	1.7	4
	medium	1	1	4	1	4	1	0	1
Dove Spring	large	2	3	4	4	4	4	1.5	4
	medium	2	3	5	1	4	1	1.3	3
Highway 51 roadcut	large	2	1	4	4	-	-	-	-
	medium	1	1	4	1	-	-	-	-
Shoofly (over oolite)	large	-	-	-	-	4	1	1.5	2
	medium	-	-	-	-	4	2	1.5	2
Castle Creek (between oolites)	large	1.3	3	4.3	3	4	2	1	2
	medium	2	1	5	2	4	3	.7	3
Birch Creek (between oolites)	large	.8	5	4.2	5	4	11	1.1	7
	medium	-	-	4	1	4	2	2	1
	small	-	-	-	-	5	2	2	2

(Table 2; Figures 5F, H, 6). Table 2 shows that the evolutionary change through time is a shift toward fewer teeth—the lower number being expressed at an earlier growth stage in later Glenns Ferry time. It can also be seen that the evolutionary change is asymmetrical– tooth reduction in the right arch is developmentally and evolutionarily earlier. The asymmetry and growth-dependence of the evolutionary change

Table 2. continued.

Locality		$Left_m$	N	$Left_M$	N	$Right_M$	N	$Right_m$	N
M. robustus (early phenotypes)									
Blackjack Butte (Oregon)	large	1	2	4	2	-	-	-	-
	medium	1	2	5	1	-	-	-	-
	small	-	-	5	1	-	-	-	-
Davis Ranch	large	1.7	7	4.9	7	4	9	1.6	7
	medium	1.6	24	4.7	20	4.1	26	1.6	28
	small	1.9	11	4.9	12	4.3	10	1.6	12
Parker Ranch	large	1	4	5	2	4	1	1.5	2
	medium	1.5	2	5	3	4	3	2	3
	small	2	3	5	5	4.3	9	2	8
Castle Creek (below oolite)	large	1	2	4	2	4	1	2	1
	medium	2	1	5	1	4	1	2	1
	small	2	1	5	4	5	1	1	1
Sand Pits	large	1.8	11	4.5	10	4	14	1.5	14
	medium	1.9	18	5	21	4.5	15	1.7	12
	small	1.8	9	5	12	4.5	8	2	5
Shoofly	large	1.8	6	4.5	4	4	3	1.7	3
	medium	1.9	27	4.8	28	4.3	24	1.8	33
	small	1.9	33	5	28	4.96	26	1.9	23
Shoofly (at Ag Lime Butte)	large	2	2	4.8	5	4.2	6	.7	3
	medium	2	3	5	3	5	2	2	2
	small	1	1	5	1	-	-	-	-
Shoofly (at Poison Creek)	large	2	1	4	2	4	2	2	1
	medium	1.8	4	5	3	4.7	3	1.5	2
Brown Creek (below oolite)	large	1.3	7	4.3	7	4	4	1.7	3
	medium	2	3	5	5	4.3	6	1.7	4
	small	2	3	5	4	5	1	-	-
M. copei									
Shoofly sec. 32, 3,060 feet	large	1.7	3	5	4	4.6	5	1.7	3
	medium	2	4	5	7	5	4	1.8	6
	small	2	1	5	1	5	1	-	-
Shoofly sec. 33, 2,990 feet	large	2	10	5	2	5	13	2	7
	medium	2	20	5	28	5	27	2	37
	small	1.9	9	5	5	5	9	1.9	14
Shoofly sec. 3	large	2	1	5	1	5	1	2	1
	medium	2	2	5	2	5	5	2	5
	small	2	4	5	4	5	2	2	2
Parker Ranch	large	-	-	-	-	-	-	-	-
	medium	2	3	5	3	5	6	2	6
	small	2	1	5	1	5	1	2	2
Schenk Ranch	large	2	2	5	3	4.6	5	2	5
	medium	2	2	5	2	5	5	2	2
	small	2	1	5	1	-	-	-	-
Tunnel Mountain	large	2	6	4.6	8	5	4	2	4
	medium	2	15	5	15	5	13	1.9	14
	small	1.9	14	5	14	5	14	2	13

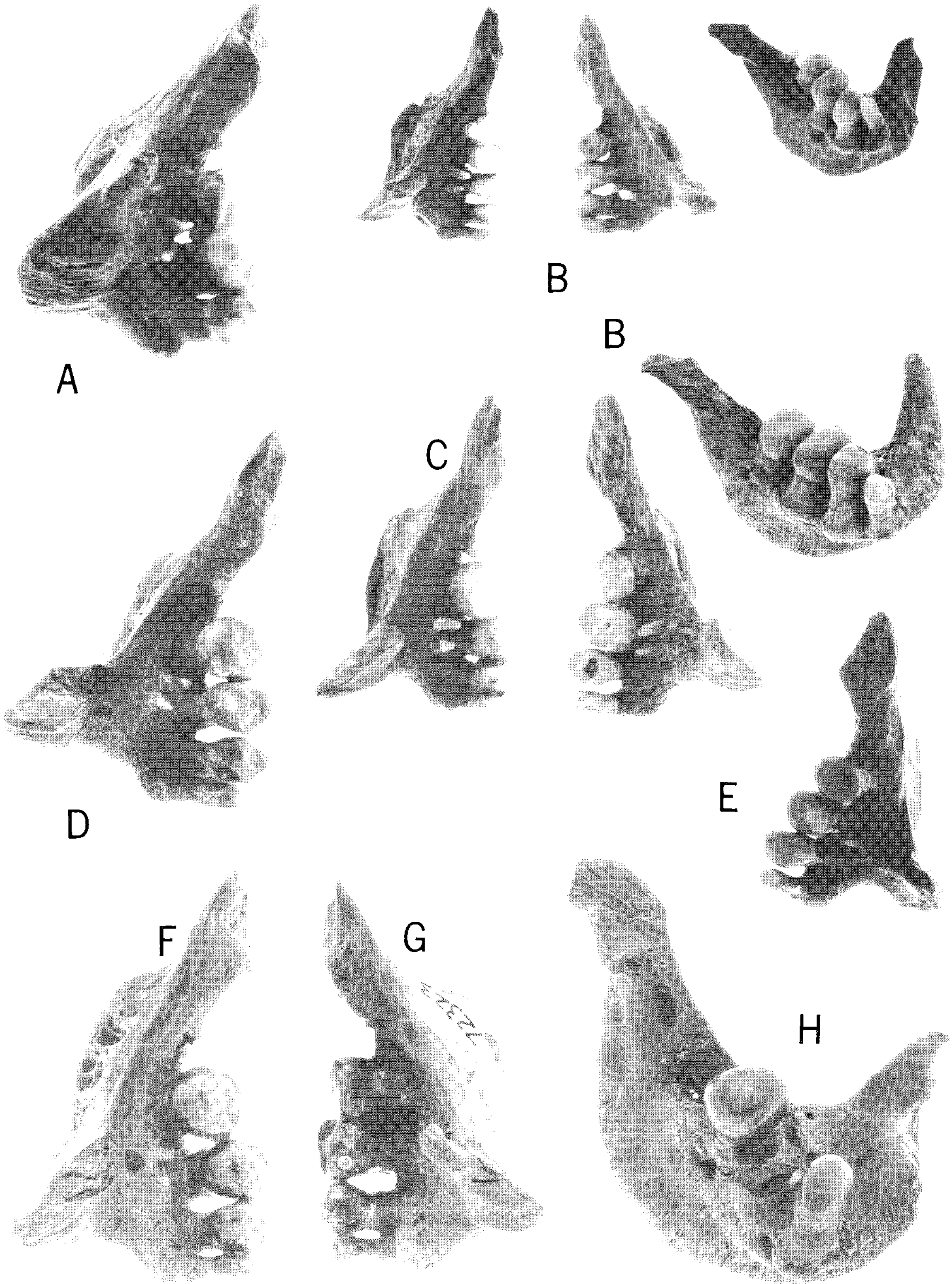

Figure 5. Pharyngeal arches of *Mylocheilus robustus* of the lower (A-C) and middle (D-H) Glenns Ferry Formation, X½. Right arches are on the right side of the page. (A) UMMP 67785, Davis Ranch; (B) 74211, Parker Ranch; (C) 67785, Parker Ranch; (D) 58121, Horse Hill; (E) 59119, Horse Hill; (F) 58137, Fossil Creek; (G) 72323, Rosevear Gulch; (H) 58139, Fossil Creek. Advanced forms show reduction in the first tooth (anterior, toward top of page) of the major row, and of the minor row, especially in right arches.

renders this system a little complicated for field-stratigraphic use, yet the abundance of these fossils makes them useful. Basically, if there are modally (but not uniformly) two teeth in the minor row (counting empty sockets) in a large sample, the stratigraphic level is lower Glenns Ferry Formation; if one tooth is the mode, the stratigraphic level is middle or upper Glenns Ferry. Similarly, the larger the proportion of small and medium right arches with four teeth, the later is the sample. Counting major teeth on left arches is surprisingly unhelpful, so left and right arches must be distinguished.

Mylocheilus robustus is rare or absent from floodplain sediments. The single countable arch from Hagerman (high in the sequence—3,280-3,300 feet in N½NE¼NW¼ sec. 5, T. 8 S., R. 13 E., in fine gray sands) is a large right arch with 4,0 teeth. If it is representative (and assuming that the base of the section is lower Glenns Ferry), it shows that the floodplain sequence in the Hagerman cliffs spans much of the time represented by the lake beds to the west.

Mylopharodon hagermanensis Uyeno (Figure 4D). This is the most abundant species of fish at Hagerman, Grand View, and Guffy Butte. It is common at Sand Point and the Bennett Creek railroad grade and uncommon in the coarse sands at the top of the Crayfish Hill section in Fossil Creek. Other specimens are isolated occurrences that show the species was in existence in the drainage but in a different habitat. This distribution reveals that it was a river, creek, and perhaps marsh dweller whose habitat was more extensive at the east part of the Glenns Ferry depositional system until the end of the lacustrine

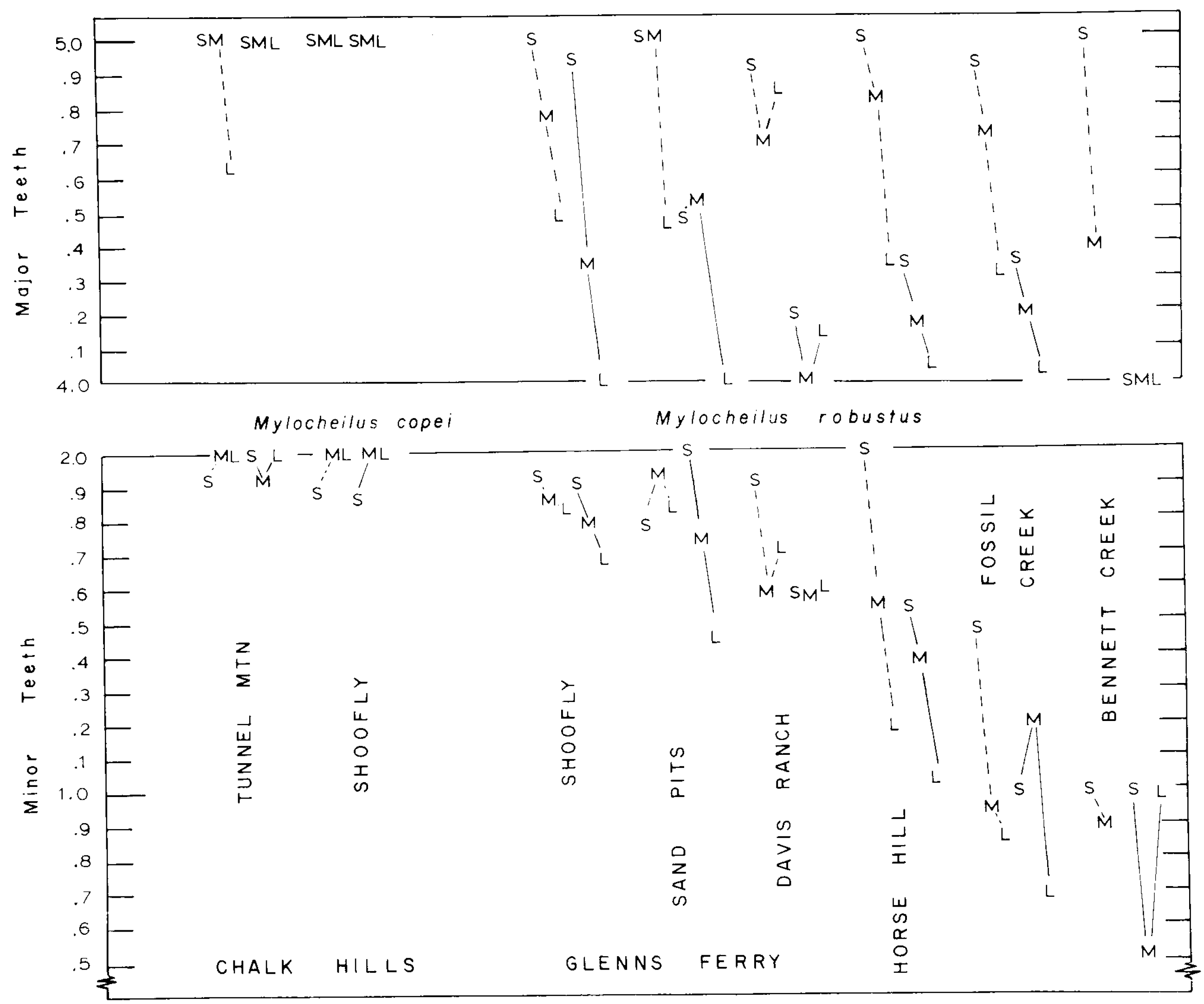

Figure 6. Trends in tooth counts of *Mylocheilus copei* and *robustus*. S (small), M (medium), L (large) specimens.

cycle, when, with its habitat, it spread west at least as far as Murphy.

The upper Chalk Hills *Mylopharodon* is morphologically intermediate between *hagermanensis* and the species described below. A similar form was collected by J. A. Shotwell and D. E. Russell from the Hemphillian Black Butte local fauna of the Juntura Formation in Malheur County, Oregon. In lowest Chalk Hills beds in Idaho, a distinct *Mylopharodon* is present.

Mylopharodon doliolus Smith and Kimmel new species (Figure 4E, F). Large pharyngeals of a *Mylopharodon* with barrel-shaped teeth have been collected from lower Chalk Hills sediments 2 miles east of Horse Hill above the Hot Spring algal limestone (Jones and others, 1978), 2 miles southwest of Horse Hill, near Adrian, Oregon, and at Brown Creek with *Smilodonichthys* (Table 1). A similar pharyngeal was collected by Steve Moore of the U. S. Geological Survey from the Esmeralda Formation of Esmeralda County, Nevada. It may be one of the most primitive North American minnows.

Holotype. A right pharyngeal arch (UMMP 74197) that was 35 millimeters in maximum length (about 2 millimeters broken from anterior limb) bearing a major tooth row 19 millimeters long with four teeth. There is one tooth socket in the minor row, opposite the position of the fourth major tooth. The anterior limb is deflected and was 12 millimeters long; the posterior limb is 16 millimeters long. The arch is 11 millimeters wide at its maximum, under the third tooth, and 7 millimeters wide under the second tooth. The rounded first tooth is 4.5 millimeters high and 3 millimeters in diameter; the second tooth is flattened terminally, 6.8 millimeters long, and 3.9 millimeters in diameter. The teeth are oval in cross section. The specimen is one of two collected from fine-grained sands at 3,010 feet in the Chalk Hills Formation (measured section in Figure 8, Swirydczuk and others, 1982 this volume).

Description. A cyprinid with stout, peglike, slightly molariform teeth (smoothly rounded unless worn flat) in the first and second positions of the major row, slightly hooked teeth in positions three to five of the major row and in the two teeth of the minor row. The tooth formula is apparently 2,5-4,2, with a tendency to lose one of the minor teeth. The arch lacks an alar expansion and a high tooth platform. The anterior limb is short but longer than in *hagermanensis*; under the second tooth the arch is enlarged and round in cross section. The postdorsal limb is elongate, but shorter, and with a less abrupt bend than in *hagermanensis*. Large individuals have widely spaced teeth. Smaller arches in the same sample have the same shape and number of teeth, but are more hooked and closely spaced.

Diagnosis. *Mylopharodon doliolus* differs from *hagermanensis* and *conocephalus* (from the Sacramento system, California) in lacking preformed grinding surfaces on the dorsal faces (opposing the basioccipital) of the anterior two or three teeth. In *doliolus* the second teeth are flattened at the tip by wear, and oppose each other. In *hagermanensis* and *conocephalus* each tooth has a characteristically constricted neck below the dentine cap. The arch has an expanded alar margin opposite the second tooth, and a sharp angle to the posterodorsal process. *Mylopharodon doliolus* differs from *Mylocheilus* in lacking preformed, flat molariform surfaces on the ends of the anterior teeth; any flatness is due to wear.

Etymology. From *doliolum* L. (little barrel) referring to shape of the anterior teeth.

Ptychocheilus arciferus (Cope). This long-jawed, long-toothed carnivore is found throughout the Chalk Hills and Glenns Ferry Formations in all facies. A similar form was collected by J. A. Shotwell and D. E. Russell from the Black Butte local fauna of the Juntura Formation in Malheur County, Oregon. *Ptychocheilus oregonesis* is found in rivers and reservoirs on the western Snake River Plain today. *Ptychocheilus* from the Bruneau Formation are not complete enough to identify to species. No stratigraphic change has been found among fossils of this abundant and widespread species.

Acrocheilus latus (Cope). This large herbivore is found throughout Chalk Hills and Glenns Ferry sediments. It and a species of *Orthodon* are abundant in the Hagerman section, and a smaller form is found in the Juntura Formation, collected by J. A. Shotwell and D. E. Russell at Black Butte. It is represented by the smaller, generalized *Acrocheilus alutaceus* in the lower Snake River and Columbia River drainage today. No useful stratigraphic variation has been found among the fossils.

Orthodon hadrognathus Smith (1975, Figure 19D) and *Orthodon onkognathus* Kimmel (1975, Figures 4G, 6A). These species are known from dentaries of the Chalk Hills and Glenns Ferry Formations. They are part of a formerly diverse group in western North America (Casteel and Hutchison, 1973; Hopkirk, 1973; Casteel and Rymer, 1975; Casteel and Adams, 1977, Figure 3D-I). The pharyngeal teeth are similar to those of *Acrocheilus* but slenderer, with a less robust arch. *Orthodon onkognathus* is limited to Chalk Hills beds in the Idaho Group; it is also found with *Chasmistes* at the Sand Hollow locality 6 miles west of Vale.

Idadon condonianus (Cope) and *Idadon hibbardi* Smith (1975, Figures 16B, 19B, 21C, D, 23; Kimmel, 1975, Figure 6B). These species are separable by development of molariform teeth in *I. condonianus*. The diagnostic rugosity on the grinding surface of the teeth of *Idadon* is present in juvenile *Lavinia* (of the Sacramento drainage) and in a cyprinid from the Miocene or Pliocene Cache Valley Formation in northern Utah. Future study might show all of these forms to be *Lavinia*. Ted Cavender and R. R. Miller (in McClellan, 1977) saw evidence that the Cache Valley form was related to *Lavinia*, and Smith and Miller (in press) have noticed features of *Lavinia* in the small cyprinid from the Bidahochi Formation of Miocene or Pliocene age in northern Arizona. Despite the potential for regional correlations, these fishes do not appear to show stratigraphically useful variation within the Idaho Group, except that they are rare or absent from the lowest Chalk Hills beds in Brown Creek, Owyhee County, and *condonianus* is not present in the upper Glenns Ferry Formation.

Gila milleri Smith (1975, Figures 15B, 18F, 21A). Variation in this species is not stratigraphically significant, but its distribution and abundance indicate a preference for fluvial habitats; it is rare in lacustrine beds. *Gila milleri* is possibly present in the Chalk Hills Formation at Parker Ranch. It is abundant in the Hagerman beds and common in upper Glenns Ferry localities. H. E. Malde collected material of *Gila* from the Bruneau Formation at Wildhorse Butte.

Richardsonius durranti Smith (1975, Figure 17C). This small fish is not yet well enough known to be stratigraphically useful. It has been found only in very fine sands in the upper Glenns Ferry Formation.

FAMILY ICTALURIDAE, CATFISH

Ictalurus peregrinus Lundberg (1975, Figures 5A-E, Plate VIIC, D, Plate VIIIA; Kimmel, 1975, Figures 5F, 6C, D). This species was described from the Juntura Formation in Oregon. Kimmel (1975) commented on the gradation between the characteristics of *peregrinus* and *vespertinus* and the failure of the original diagnosis to separate the species. Nevertheless, Miocene forms of the lineage have, on the average, a shorter postventral spine on the cleithrum, with a shorter rugose patch which has tubercles randomly spaced. The boss over the socket for the pectoral spine is more bulbous in *peregrinus*. On the pectoral spine of this species the proximal posterior denticulations are usually on a central ridge (compare below). Kimmel (1975) noted a high proportion of abnormal variants in several populations of this species in southwest Oregon.

Ictalurus vespertinus Miller and Smith (1967, Figures 6, 7; Lundberg, 1975, Figure 5, Plates VII-IX; Smith, 1975, Figure 24). If large, well-preserved specimens are available, this species is usually distinguishable from *I. peregrinus*. *Ictalurus vespertinus* has a longer cleithral spine with a large patch of generally aligned tubercles. The convexity over the socket for the pectoral spine is not as elevated as in *peregrinus*. The proximal posterior dentations of the pectoral spines are usually aligned in a groove ventral to the posterior ridge. The species is common throughout the Glenns Ferry Formation. It forms a larger proportion of the fish fauna from fluvial deposits than from lacustrine deposits.

FAMILY CENTRARCHIDAE, SUNFISH

Archoplites taylori Miller and Smith (1967, Figures 8, 9; Smith, 1975, Figure 25; Kimmel, 1975, Figure 6E). This group was widespread in the Miocene of western North America from southern Nevada to Alaska (Smith and Miller, in press). Its morphology is surprisingly uniform in the Idaho Group except for slight variation in dentaries and nonstratigraphic variation in the striation of the opercles. Dentaries from the Chalk Hills Formation (especially lower) tend to have a wider tooth patch than Glenns Ferry specimens.

The most common condition of the opercle is strongly striate externally (Smith, 1975, Figure 25A). This is the condition from throughout Hagerman cliffs and at Rosevear Gulch. Nonstriate opercles have been collected at Crayfish Hill in Fossil Creek, Horse Hill, upper Henderson Creek, and in the regressive beach deposits at the top of the Shoofly section. At Sand Point, the type locality of *A. taylori*, both types of opercles are present. At the Bennett Creek railroad grade a large, intermediate specimen was collected. The significance of this variation is not yet understood, but it seems to be correlated with habitat, not time.

Archoplites drops out of the fauna before the time of the Grand View local fauna. The only surviving representative of this genus (*A. interruptus*) lives in the Sacramento system.

FAMILY COTTIDAE, SCULPINS

Cottus calcatus Kimmel (1975, Figure 3K). This strange species is occasionally present as rare weathered specimens at all levels except the Pleistocene. Its relationship to other sculpins in the system seems remote.

Cottus bairdi Girard. This small, Holocene species has not been collected from any of the Pliocene or earlier samples from the Idaho Group. It is known only from the Grand View local fauna, where it is the only sculpin present.

Kerocottus divaricatus, *pontifex*, and *hypoceras* Cope (Linder, 1970, Figure 1; Smith, 1975, Figures

26, 27A, B, C, 28; Kimmel, 1975, Figure 6G; Figure 3F, G, H). This group of species is known only from the Glenns Ferry Formation, for which it is a reliable indicator. Co-occurrence with Miocene *Mylocheilus inflexus* was recorded by Kimmel (1979) from the stream bed in Brown Creek, but contamination is probable. The genus is absent from Hagerman, indicating avoidance of the floodplain, but is well represented at Sand Point and Bennett Creek, apparently indicating lacustrine environments at or near those localities.

Kerocottus divaricatus (Figure 3F) is characterized by small sensory canal pores on the preopercle. It is the first species of *Kerocottus* to appear in the sequence, in the basal sands of the Glenns Ferry Formation, and it is present in almost all large samples above that level. *Kerocottus pontifex* (Figure 3G) is characterized by large sensory canal pores. It is represented by a single specimen in the basal sands, and is otherwise absent until rather high in the section. It is abundant in the fine sands at Fossil Creek and near Oreana, and in the regressive beach sands at the top of the Glenns Ferry lacustrine deposits from Shoofly to Castle Creek. *Kerocottus hypoceras* (Figure 3E) is characterized by the absence of sensory canal pores on the preopercle. It is present at the localities where pontifex is abundant, but not below. All three species are present at the Bennett Creek railroad grade, but not above that level.

Myoxocephalus antiquus Smith (1975, Figures 26I, 27D; Figure 3I). This is a sculpin of uncertain affinities, characterized by preopercles with straight spines in one plane and medium-sized sensory canal pores. It is known only from Fossil Creek and is therefore of limited stratigraphic use. A small fragmentary dentary with medium-sized pores was collected from the Tunnel Mountain locality of the Chalk Hills Formation in Malheur County, Oregon (Kimmel, 1975, Figure 6K).

Myoxocephalus idahoensis Smith (1975, Figures 27E, 28; Figure 3G). This species is known from numerous skull bones. It is characterized by large sensory canal pores similar to those of *Myoxocephalus thompsoni* of arctic North America and deep waters of the Great Lakes. It is restricted to latest Pliocene fine-grained lacustrine sands of the Glenns Ferry Formation: at Fossil Creek, nearby Henderson Creek, and Picket Creek, at regressive beach sands from Shoofly to Castle Creek, at Sand Point, and at the Bennett Creek railroad grade. It would appear to be a good stratigraphic indicator, based on the abruptness of its first and last occurrence. Its environmental significance lies in its lacustrine habitat and its occurrence at the Sand Point and Bennett Creek localities.

STRATIGRAPHIC SUMMARY

Distribution patterns of the fishes described above and in Table 1 allow clear separation of the Chalk Hills and Glenns Ferry Formations. The Chalk Hills Formation can be subdivided into three zones. The Glenns Ferry Formation includes a diverse and subdivided Pliocene assemblage and a strikingly reduced, modern-looking Pleistocene fish fauna. The Pliocene portion of the Glenns Ferry Formation can be further classified into facies and time stages.

CHALK HILLS FORMATION

The unconformity at the upper limit of the Chalk Hills Formation marks the end of a faunal zone characterized by *Hucho larsoni*, *Mylocheilus inflexus*, and *Mylocheilus copei*. *Rhabdofario carinatum* and *Ictalurus peregrinus* are associated with the Chalk Hills Formation by definition; they are transitional to their Glenns Ferry counterparts. The Chalk Hills beds are also characterized by the absence of *Prosopium*, *Kerocottus*, *Myoxocephalus*, and usually *Chasmistes*.

In Brown Creek there are older beds characterized by the Chalk Hills species listed above and *Smilodonichthys*, *Mylopharodon doliolus*, and *Orthodon onkognathus*. Deposits of the *Smilodonichthys* zone consist of interbedded, coarse-grained sands and silts suggesting fluvial deposition; the fossils are primarily fish and wood, suggesting a beach environment. No discontinuity has been discovered between these beds and overlying Chalk Hills sediments. Basalts within the lower Chalk Hills Formation at Hot Creek, south of Horse Hill, have been dated at 8.4 and 8.2 million years by Armstrong and others (1975). The Brown Creek Tuff underlying the Chalk Hills Formation in Brown Creek has been dated at 10.7 and 11.1 million years by Neill (in Ekren and others, 1978).

Above the *Smilodonichthys* zone but well below the lower Horse Hill ash layer are sands with *Mylopharodon doliolus* and *Orthodon onkognathus* and the other Chalk Hills species. Two miles east of Horse Hill this zone overlies the Hot Spring limestone, an algal carbonate of 30 square miles found in the shallow-water transgressive lacustrine sequence formerly thought to be basal Glenns Ferry (Jones and others, 1978). A similar "middle Chalk Hills" fauna occurs in sands near Adrian, Oregon, below the ash correlated with the lower Horse Hill ash layer (Swirydczuk and others, 1982 this volume; measured section, Figure 3A).

Above and below the lower Horse Hill ash layer, which is at an elevation of 3,025 feet, 2 miles east of

Horse Hill (Swirydczuk and others, 1982 this volume; measured section, Figure 8; Table 1), is a characteristic upper Chalk Hills fauna (as defined above, but lacking *Orthodon onkognathus* and with intermediate *Mylopharodon*). The same fauna is found 2 miles southwest of Horse Hill, at Parker Ranch, Twentymile Gulch, the Shoofly area, and east of the Bruneau River (Table 1). Fission-track dates by Kimmel (1982 this volume) suggest that ashes low in this general zone (in the Shoofly area) are about 8 million years old. Kimmel shows that the uppermost Chalk Hills sediments dated are 5 to 6 million years old. At least 1 million years are missing in the erosional interval separating the Chalk Hills and Glenns Ferry Formations. This is not to say that lacustrine habitat disappeared from the basin—Table 1 shows that most of the lake species were still present, though slightly modified, when the Glenns Ferry lake transgressed the southern slopes of the former Chalk Hills basin.

GLENNS FERRY FORMATION

The oldest fission-track date on glass in the Glenns Ferry lacustrine beds is 3.2 million years from basal sands above the unconformity in Brown Creek, near Oreana in Owyhee County. Other Glenns Ferry dates from that area are around 2 to 2.5 million years (see Kimmel, 1982 this volume, for discussion). Glass shards in the Peters Gulch ash, near the base of the Hagerman cliffs, gave an anomalously old fission-track date (Kimmel, 1979), but Izett (1981) dated zircons from this ash at 3.75 ± 0.36 million years. Ashes near the middle of the Hagerman section and the Deer Gulch lava yield potassium-argon dates of 3.3, 3.2, and 3.5 million years (Evernden and others, 1964; Bjork, 1970). This correlation suggests that the lower part of the Hagerman section is older than Glenns Ferry beds in Owyhee County and that part of the upper section at Hagerman is time-equivalent to lacustrine beds in Owyhee County. This is consistent with the summary by Malde and Powers (1962, p. 1207):

> *The lower 400 feet of floodplain facies at Hagerman grades westward into a lacustrine facies at Deer Gulch 8 miles southeast of Glenns Ferry and into arkosic deposits between Clover Creek and Glenns Ferry. These arkosic deposits are overlain by 650 feet of lacustrine deposits at Glenns Ferry. A floodplain facies in the upper part of the northern canyon wall at Glenns Ferry grades southwestward into the fluvial facies at Hammett. A floodplain facies at Castle Creek merges northwestward with yellow silt of a lacustrine facies near the mouth of Sinker Creek, 8 miles distant.*

The lacustrine beds referred to by Malde and Powers are generally structureless, bioturbated silts near the axis of the basin. They contain few fish fossils and few ash beds; they are clearly a deep-water lacustrine facies.

We interpret part of the fluvial facies of Malde and Powers (1962, p. 1206), at least as exposed at Bennett Creek, at Horse Hill near the head of Bruneau Valley 8 miles south of Bruneau, and at Fossil Creek along the paved road 17 miles northwest of Grand View (but not at Sand Point), as shoreface deposits. They are well-sorted fine sands with some cross bedding but no channels or point bars. They have abundant fossil fishes, locally common mollusks, birds such as cormorants and grebes, but few mammalian remains. The fish fauna is strikingly different from that of the Hagerman and Grand View floodplain deposits, containing more diversity, an abundance of exceptionally large individuals, and forms expected to be restricted to lakes. We propose the following list of lacustrine species, interpreted as being good indicators of lake deposits and unlikely in fluvial deposits: *Kerocottus divaricatus, pontifex*, and *hypoceras*; *Myoxocephalus idahoensis*; and *Mylocheilus robustus*. If these fish occurred in the Hagerman Cliffs (for example near channel deposits), our hypothesis would be rejected, but they are not represented among the thousands of fish fragments from the floodplain deposits, except for one pharyngeal arch and several isolated teeth of *Mylocheilus robustus* at Hagerman. *Prosopium prolixus*, *Idadon*, *Catostomus owyhee*, and *C. shoshonensis* are abundant in lacustrine but uncommon in floodplain sediments. On the other hand, *Mylopharodon hagermanensis* is abundant in floodplain sediments and uncommon elsewhere, except at Sand Point and Bennett Creek, which also have mammalian remains. *Ictalurus* and *Catostomus cristatus* are more abundant in floodplain than in lacustrine environments.

By these criteria, the beds at Sand Point and Bennett Creek have faunas intermediate between floodplain and lacustrine aspect. In the Laurentian Great Lakes such a faunal mixture would be found near the mouths of rivers or in the lower few miles of large rivers.

At Sand Point, lacustrine fishes are present but not abundant; *Mylopharodon hagermanensis* and mammals are common. The mammals include muskrat, horse, proboscidian, pocket gophers, rabbits, and voles. Distinct mollusks are present (Hibbard, 1959; Malde and Powers, 1962). The sedimentary units are laterally restricted or variable, and vertically variegated. A fluvial environment near the lake is indicated.

At the Bennett Creek railroad grade lacustrine fishes are abundant, and *Mylopharodon* less common. Mammals are rare, but this is the type locality of *Prodipodomys idahoensis*, a kangaroo rat that might have been living in sand dunes. The proximity and similarity of this lacustrine assemblage to the fluvial assemblage at Sand Point suggests that the Bennett Creek sediments are lacustrine, but near the mouth of a major tributary.

To the west, particularly south of Bruneau and Grand View, most fish-bearing beds of the Glenns Ferry Formation are basal transgressive beach deposits and overlying shoreface fine sands. The beach deposits generally lie between 2,800 and 3,400 feet, 6 to 12 miles southwest of the Snake River, and dip about 3 degrees northeast. The overlying shoreface sands (fluvial sands of Malde and Powers, 1962) are best seen between 2,850 and 3,100 feet. They are generally missing from the higher flanks of the basin, having been eroded prior to deposition of Pleistocene alluvium. Exceptions are found at 3,400 feet southwest of Horse Hill and in upper Hart Creek (Table 1). The shoreface sands grade into the deeper lacustrine silts in the axis of the basin. The relationship of these facies must be taken into account in attempts to correlate time-equivalent units through the basin. The three main nearshore deposits discussed here are the base of the Shoofly oolite, the Horse Hill beach of quartzite cobbles, and the upper Shoofly (regressive) beach.

The Shoofly oolite (Swirydczuk, 1980; Swirydczuk and others, 1979, 1980a, 1980b, 1981, 1982 this volume) crops out in a northwest-southeast belt 30 miles long, from southwest of Murphy to south of Grand View, attaining a thickness of more than 100 feet. Most of the oolite is underlain by well-sorted, coarse, fossiliferous sands which in turn lie unconformably on fine offshore lacustrine deposits of the Chalk Hills Formation. Based on the lack of mammals and the abundance of mollusks, disarticulated fish bones (including occasional reworked Chalk Hills species), wood, and clasts of underlying Chalk Hills silt, the basal sands are interpreted as beach deposits. The oolite makes up a series of nearshore progradational deposits conformably overlain by lacustrine silts and ashes deposited in deeper water. The overall sequence is thus transgressive.

Fossil fishes in the basal sands include the early form of *Mylocheilus robustus* (modally five teeth in the major row and two teeth in the minor row of the right arch, except in large specimens). With one peculiar exception (*K. pontifex* at the Sand Pits), *Kerocottus divaricatus* is the only sculpin present. Lateral variance in fossils along the oolite and associated sands is not significant and provides no evidence of time transgression. Occasional specimens of *M. robustus* within the oolite indicate little advancement from the primitive form, except at Parker Ranch (Table 2). The sample from Davis Ranch is unusual and may represent a slightly advanced form. Sampling variation and probable evolutionary fluctuation prevent fine-scale stratigraphic use of subspecific variation by itself. Sands directly above the oolite have not produced large enough samples of fossils to be decisive.

The next younger unit is the Horse Hill beach deposits (Figure 6, Table 2), according to the more advanced state of *Mylocheilus robustus* and the definite presence of *Kerocottus pontifex*. Malde and Powers (1962, p. 1207) refer to a lag concentration of quartzite cobbles south of Bruneau as being possibly correlated with a conglomerate 15 miles south of Glenns Ferry. The origin of the cobble unit is not obvious. The cobbles were probably transported by the ancestral Bruneau River from Paleozoic deposits in the Jarbidge Mountains, 70 miles to the south. They occur in a single layer a few feet above the Chalk Hills Formation. The entire unit covers about 50 square miles, dipping north from about 3,300 feet south of Horse Hill to about 2,900 feet between Horse Hill and Bruneau. The cobbles are largest (over 1 foot long) at the north end of Horse Hill, and diminish in size toward the edges of the unit. They armour Horse Hill from erosion by Sugar Creek. Abundant fish fossils and mollusks (*Sphaerium*) are cemented among the cobbles in a coarse, limonitic, and occasionally phosphatic matrix that fines upward to offshore sands within a few feet. Glenns Ferry lacustrine silts and ashes continue upward several hundred feet. The presence of lake fishes and clams, along with cormorants and grebes, but no mammals in the cobble unit, constitutes the basis for referring to it as a beach. The fining-upward sequence is interpreted as transgressive. The composition of the fish fauna suggests that the Horse Hill beach might be a slightly later southeastward extension of the beach deposits found under the Shoofly oolite.

Lacustrine silts directly over the beach deposits do not have demonstrably younger faunas. Closer to the center of the basin, however, in the Fossil Creek area between 2,850 and 3,020 feet, the fauna is decidedly advanced. These fine, micaceous (sometimes coated) sands have all four species of *Kerocottus*, two kinds of *Myoxocephalus*, and advanced *Mylocheilus robustus*. They are rich in ostracods (Jones and Anderson, 1965). In the lower Fossil Creek area (Crayfish Hill, Table 1), the shoreface sands coarsen upward to a fine gravel with channels (2,875 feet) and *Mylopharodon hagermanensis*, and are interpreted as deposits laid down by the regressive phase of the Glenns Ferry system.

Other possible examples of the regressive beach are preserved in Shoofly, Birch, and Castle Creeks. A poorly sorted, thin (4-inch thick) brown sand unit is traceable over 15 miles at an elevation of 2,740 to 3,300 feet, dipping to the northeast. The fauna is distinctly advanced, with all three species of *Kerocottus*, as well as *Myoxocephalus idahoensis*, advanced *Mylocheilus robustus*, and some *Mylopharodon hagermanensis*. Pleistocene alluvial gravels or poorly sorted sands appear a few feet above this horizon. At Shoofly Creek it is capped by an extensive section of upper Glenns Ferry Formation floodplain and marsh deposits.

Stratigraphically near the lake beds are Sand Point fluvial deposits and Bennett Creek shoreface sands already discussed. Their species are the most advanced we have seen (Table 1), and represent the last occurrence of a diversity of minnows, suckers, sculpins, catfish, and sunfish.

If the above inferences about the regressive beaches and environments are correct, they imply that lake levels dropped about 400 feet in a short period. The timing of this event was probably early Pleistocene (Kimmel, 1982 this volume). Its cause was probably the capture of the upper Snake River through Hells Canyon (Wheeler and Cook, 1954).

Following drainage of the lake, floodplain deposition advanced westward along the axis of the basin. These beds are seen at Jackass Butte (Grand View), Wildhorse Butte (Shotwell, 1970), and in our collection at Guffy Butte. These early Pleistocene deposits have a depauperate fish fauna (Table 1) of small, essentially modern fishes. In contrast to the interval between the Chalk Hills and Glenns Ferry lakes, during which lake fishes found a refuge, the elimination of lake habitat at the close of deposition of the Glenns Ferry Formation must have been complete. The middle Pleistocene Bruneau lake beds also have only the sparse modern fauna.

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