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A Fossil Trionychid Turtle from the early Tertiary Chuckanut Formation of Northwestern Washington

Abstract

Washington's vertebrate fossil record is so sparse that every discovery deserves careful scrutiny. A fossilized turtle carapace found in 1960 in fluviatile sandstone of the Chuckanut Formation of western Whatcom County was originally identified as a member of the Testudinoidea superfamily, and an adjacent bone fragment was considered to be evidence of some larger animal. Re-examination indicates that the carapace represents a member of the Trionychidae (soft-shelled turtles). Computerized axial tomography suggests that the nearby bone probably came from the turtle. Trionychid fossils are abundant in early Tertiary rocks, but their remains have not been found in younger rocks in the northwest region. The only extant trionychid found west of the Mississippi is *Trionyx spiniferus*, which inhabits small areas of eastern Montana and the Colorado River region of the southwest. This restriction in geographic range probably resulted from global cooling that started in the late Eocene, and by habitat destruction caused by episodes of mountain building that began a few million years later.

Introduction

The faunal record from the early Tertiary is sparse even though extensive sedimentary deposits from this period are exposed on both sides of the Cascade Range. These beds of shale, siltstone, sandstone, conglomerate, and coal were deposited by meandering rivers that flowed westward across the broad floodplain that covered much of western and central Washington prior to the uplift of the North Cascades. Of these deposits, the 6,000 m thick Chuckanut Formation has received the most attention from geoscientists (Pabst 1968; Johnson 1984; Mustoe 1993; Mustoe and Gannaway 1997). Plant remains are abundant in Chuckanut strata and animals are represented by a variety of tracks. The only vertebrate body fossils that have been found are the impression of the interior surface of the carapace of a turtle and a nearby bone fragment (Figures 1, 2).

The 18 x 13 x 7 cm specimen was collected in 1960 during construction excavations south of Bellingham at Clark Point (T 37 N, R 2 E, SW corner Sec 13) but recognition of the fossil as a turtle carapace did not occur until two decades later when a visiting geologist noticed the rock at the Clark family home (Guthrie 1981). Bedrock at Clark Point consists of arkosic sandstone of the Padden Stratigraphic Member, the youngest subunit of the Chuckanut Formation. Johnson (1984) and Mustoe and Gannaway (1997) presented conflicting interpretations for the stratigraphy of the Padden Member, but its age is probably late Eocene based on structural relationships and paleoclimatic evidence. Mustoe and Pevear (1983) described the poorly-preserved carapace as a member of the Superfamily Testudinoidea, a large group that includes pond turtles and land tortoises. They guessed that bone fragment exposed in cross-section view on one side of the specimen was part of a rib bone from some larger animal. Because turtles have ribs that are fused to the adjacent bony carapace layer, this bone was presumed to have come either from bones of a land-dwelling mammal that were washed into the fluvial sediments, or to be skeletal remains from an aquatic reptile. The latter possibility is consistent with discoveries of fossil crocodiles in the Green River Formation of Wyoming (Grande 1984), correlative in age to the Chuckanut Formation. Because the fossil was softer than the enclosing matrix, the decision was made not to attempt to reveal the bone by mechanical excavation for fear of destroying the specimen. In 1996 geology student S. P. Girouard, Jr., re-examined the specimen and decided that both of Mustoe and Pevear's (1983) interpretations were incorrect. This paper presents his findings.

Anatomical Features of the Carapace

Although the impression of the carapace preserves relatively few anatomical details, several characteristics suggest that the specimen represents a member of the Superfamily Trionychidae

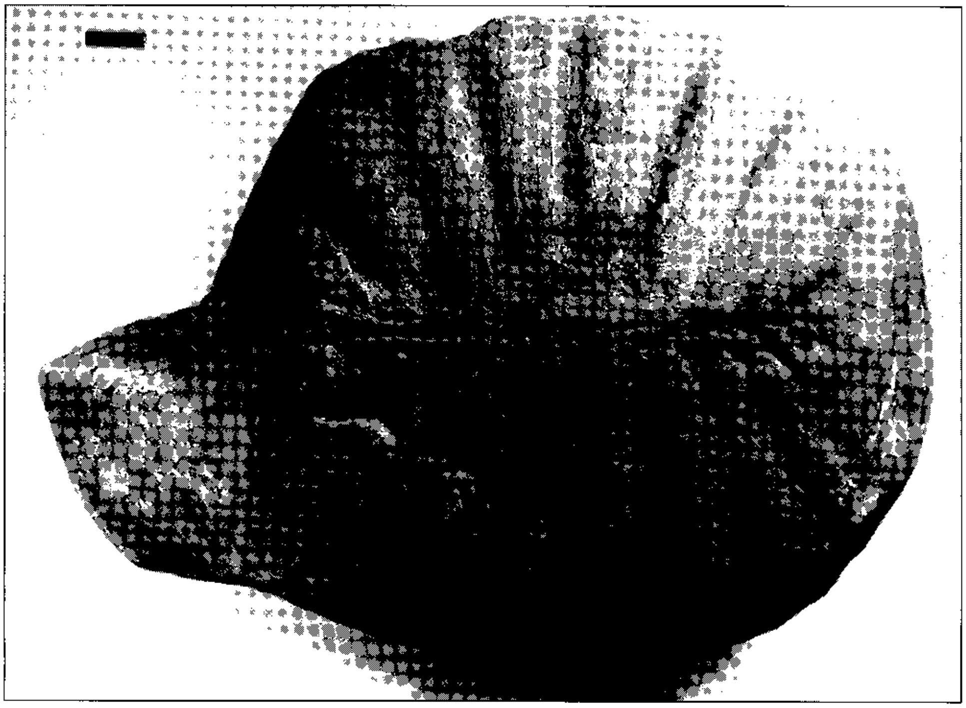

Figure 1. Chuckanut turtle fossil, showing impression of ventral surface of carapace. Broad corrugations represent fusing of the ribs to form a continuous bony layer. These corrugations meet at a midline axis that represents eroded neural arches of the vertebral column. Scale bar = 1 cm. Photos used for figs. 1 & 2 have been reversed from right to left to allow easier comparison with the radiograph in fig. 6.

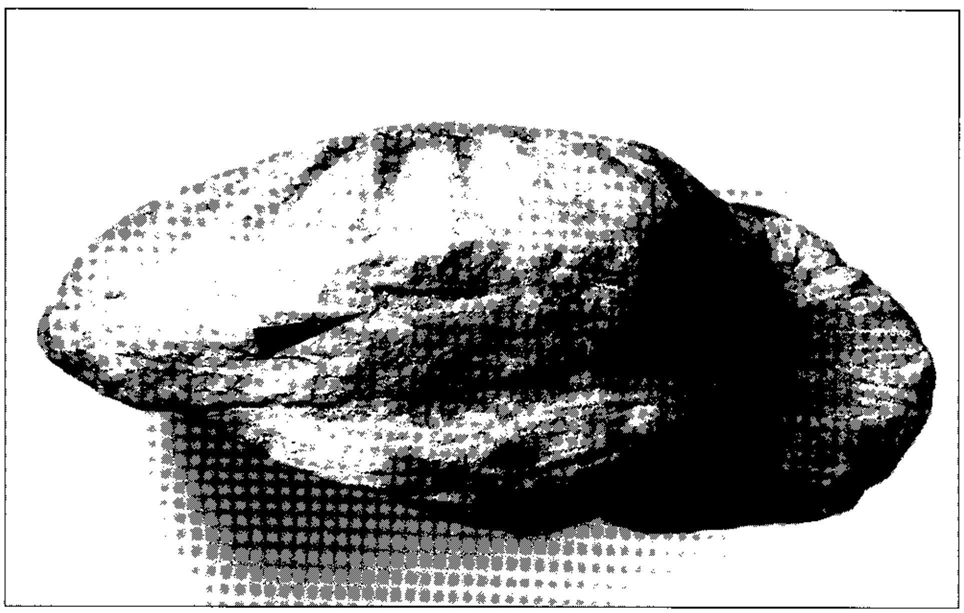

Figure 2. Side view of specimen, with bone fragment marked by arrow. (Same scale as Figure 1).

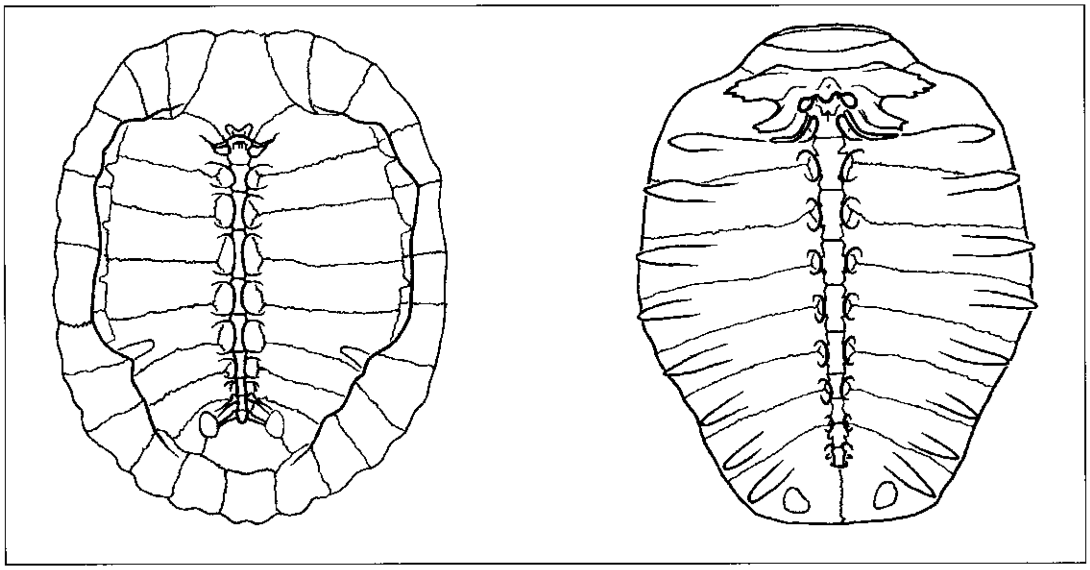

Figure 3. Internal view of two types of carapace architecture. Left: *Trachemys scripta*, showing the ring of peripheral plates that surround the upper shell in all turtles except trionychids. Right: *Lissemys punctata*, a trionychid. Adapted from Meylan (1987).

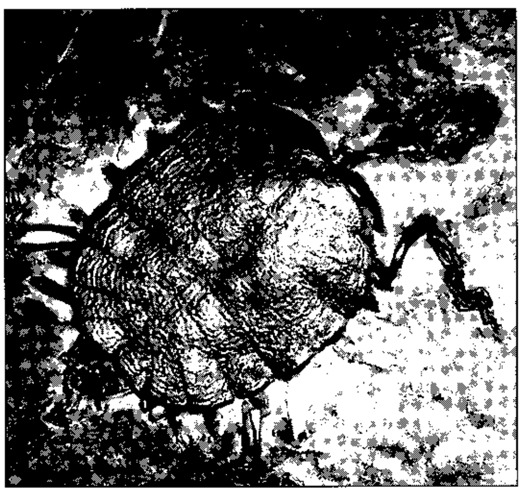

Figure 4. Fossil soft-shelled turtle *Trionyx messelianus* from Eocene shale at Messel, Germany, showing dorsal view of carapace. The bumpy texture of the dorsal surface helps the bony plates provide a strong substrate for the overlying leathery carapace, as illustrated in Figure 5. The Chuckanut specimen appears quite different from either of these figures because the fossil shows the ventral surface. Photo courtesy of Senckenberg Museum, Frankfurt.

(soft-shelled turtles). Other turtles have carapaces that have rigid margins composed of 20 to 22 bony plates, but trionychids have flexible margins and lack peripheral bones (Figures 3, 4). The cartilaginous margin typically comprises approximately one half of the total carapace length. In many species the distal ends of the ribs project beyond the perimeter of the central bony disk, but other trionychids lack these projections (Meylan, 1987). An important distinguishing characteristic of trionychids is the absence of epidermal plates (scutes). Instead, the shell's external surface is covered with leathery skin (Figure 5). This absence of horny scutes is shared only by the huge leatherback sea turtles, Family Dermochelyidae (Ernst et al. 1994).

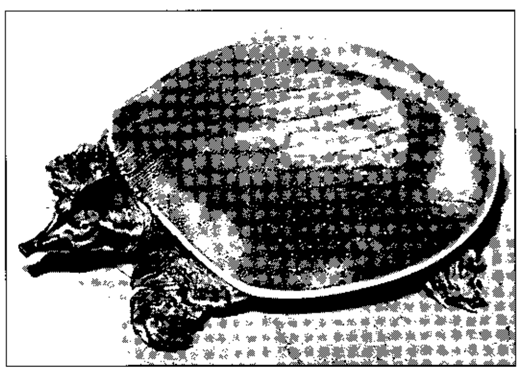

Figure 5. The living *Trionyx spiniferus* (Eastern Spiny Softshell) shows the leathery carapace surface characteristic of members of the Trionichidae. Photo by F. J. Obst.

Possibly the Chuckanut fossil represents an incomplete carapace where peripheral bones were either disarticulated prior to fossilization, or destroyed later by erosion. A more likely interpretation is that the absence of these marginal plates is evidence that the fossil is from a trionychid. Because the specimen preserves an impression left by the interior surface of the carapace, it is not possible to determine the nature of the original outer surface. However, a partially preserved layer of mineralized bone bears no trace of impressions (sulci) that commonly form along seams between adjacent scutes. The shallow convex corrugated exterior surface bears a strong resemblance to shell shapes of extant species of *Trionyx* and its kin, though some other types of turtles have similar contours.

The 12 cm length of the Chuckanut fossil is small compared to carapace lengths of most modern and fossil trionychids. Large extant members have bony disks that exceed 50 cm, and for most species the adults have carapacial disk lengths of 20-30 cm. Of 23 living species, only five have disks less than 20 cm (Meylan 1987). The Chuckanut specimen may represent an unusually small variety, but it may also be remains of a juvenile because in contrast to many other types of turtles, among trionychids carapace shape remains relatively constant during growth.

Evidence from Computerized Axial Tomography

The sandstone block also preserves a fossil bone visible in cross section as a flattened asymmetric 26 x 6 mm oval, comprised of a 0.5 mm thick cortical layer surrounding a porous central zone (Figure 2). In May, 1996 a computerized axial tomography analysis of the specimen was performed using a General Electric Model 9800 CT scanner. The value of CT technology for the study of vertebrate fossils was first demonstrated by Conroy and Vannier (1984), and the technique was quickly adopted by vertebrate paleontologists (for a detailed overview see Clark and Morrison 1994). The Chuckanut specimen was subjected to 18 scans on the coronal (anterior to posterior) and sagittal (medial to lateral) planes , usually at an interval of 3 mm between successive scans and at an accelerating voltage of 120 KV at 100-170 MA and a scan rate of 37.5 mm/s. Because of the density of the matrix the scan images are somewhat indistinct, but resolution is sufficient to show the general shape and dimensions of the hidden bone fragment (Figure 6).

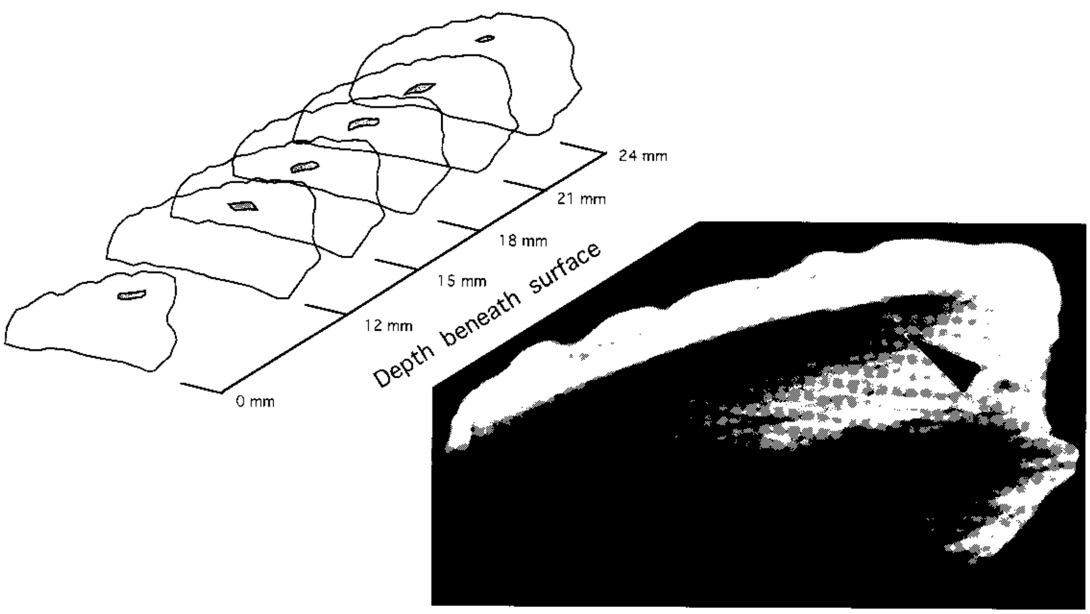

Figure 6. Tracings made from five CT scans show successive cross-section views of bone fragment that extends approximately 30 mm into the sandstone matrix. Photo shows actual CT scan image at 12 mm depth, with included bone marked by arrow. The undulating surface at the top of the slab represents the carapace impression. The size and flattened shape suggest that the bone is probably either a fragment of plastron or internal skeleton.

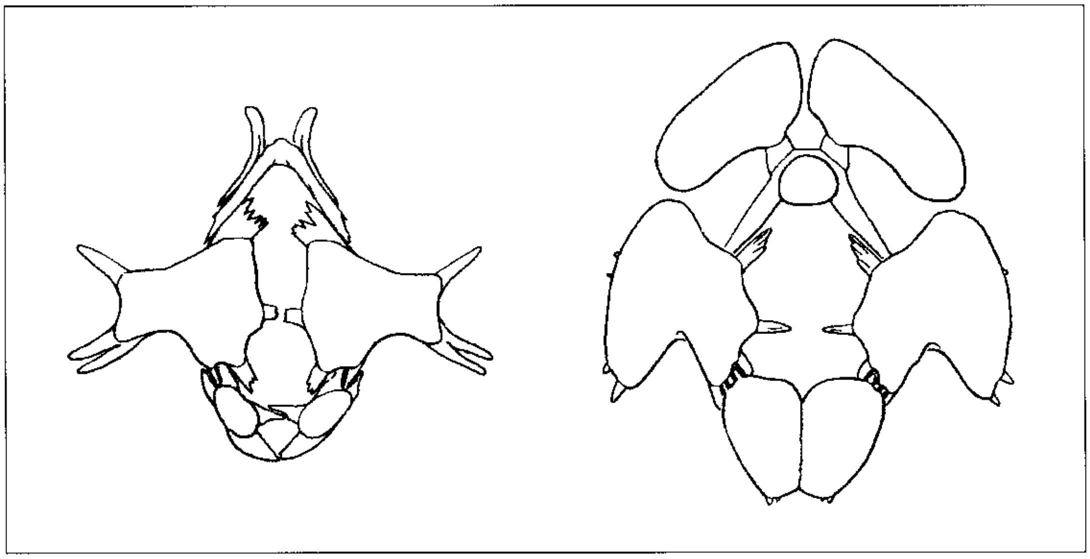

Figure 7. Sketches of trionychid shell architecture, shown in ventral views. Adapted from Meylan (1987). Left: *Trionyx ferox*. Right: *Lissemys punctata* .

The preserved portion of the bone is a thin, subtriangular structure that extends for approximately 30 mm into the matrix. Although an asymmetric flattened oval cross-section can be observed at its exposure at the surface of the slab, the bone has a compressed trapezoidal cross section near the apex. Mustoe and Pevear (1983) assumed the exposed cross-section represented a rib bone from a larger animal, a diagnosis that is contradicted by the radiographic images. Instead, the bone is probably a fragment of the plastron (Figure 7) or fragment from the pelvis or shoulder girdle (Figure 8). More exact identification is impossible because of the variations in skeletal architecture found among different trionychid genera and the lack of resolution of the CT scans. The geometry of plastron shows much variation among extant species, but all trionychids have flattened plate-like plastral elements whose size relative to the carapace falls within the dimensional ratios of the Chuckanut specimen. However, pelvic girdle and shoulder bones also have elements that could be broken to produce the object shown in the CT scans. Although we can not disprove the possibility that the bone fragment represents some other animal, the simplest explanation is that both parts of the fossil are from a single turtle.

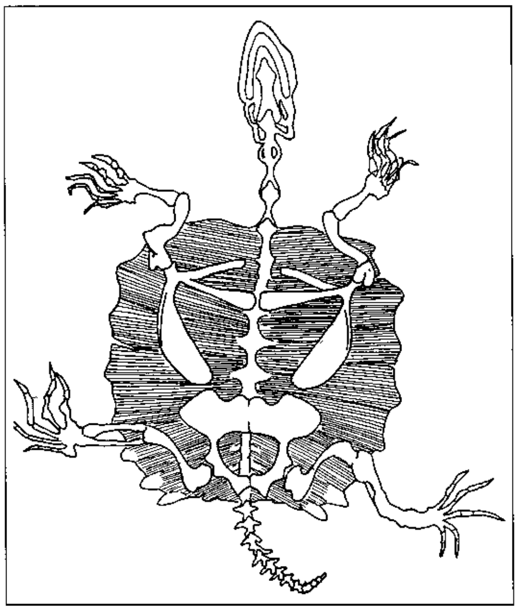

Figure 8. Internal architecture of *Trionyx gangeticus* (Ganges Softshell), with lower shell (plastron) removed to show ventral view of carapacial bones, limb bones, and internal skeletal elements.

Discussion

Members of the Trionichidae include 22 extant forms and approximately 230 fossil species that date back to the late Mesozoic. Nearly all of the extinct members have been placed in the genus *Trionyx*, creating a taxonomic wastebasket that includes many fossils that lack anatomical features found in living members of the genus (Gaffney 1979). Phylogenetic relationships among modern trionychids are not well understood, and important taxonomic issues remain unresolved. Meylan (1987) used cladistic analysis to divide *Trionyx* into nine genera, a revision that is not universally accepted (e.g., Webb 1990). For these reasons we have not classified the Chuckanut specimen at the genus level.

Trionychids presently live in North America, Africa, Asia, and the Indo-Australian archipelago. Fossil forms indicate their range once included South America and Europe as well. Three species presently live in North America. *Trionyx mucticus* (smooth softshell) inhabits the Mississippi Valley region, *T. spiniferus* (spiny softshell) dwells in a large area of the central and southeastern U.S. as well as small areas of Vermont, eastern Montana, and the Colorado River drainage of the southwest. *T. ferax* (Florida softshell) occurs only in Florida and border area of adjacent states (Ernst et al. 1994). Modern trionychids dwell in aquatic environments that range from swamps and marshes to rivers and lakes. They are predators that consume snails, insects, crayfish, small fish, and frogs, depending to a lesser extent on scavenging and consumption of aquatic plants. Among turtles they are some of the fastest swimmers (Webb 1962), and their unique shell architecture allows them to make rapid predatory strikes against fish and other swimming prey. The flexible carapacial margin makes trionychids well adapted for muddy environments, and they use undulating motions of the shell's edge to dig into the bottom sediment for protection (Ernst et al. 1994). Trionychids typically have elongated necks and long pointed snouts, features that allow them to remain concealed in mud, strike at prey or reach to the surface to breath.

The geographic range of trionychids included much of the western U.S. during the early Tertiary. An unidentified trionychid is the most common turtle in the Eocene Green River Formation of Wyoming (Grande 1984), and shell fossils are so common in the nearby Eocene Bridger Formation that a pioneer vertebrate paleontologist declared "Trionychidae ran riot" (Hay, 1908, p. 39). Rich et al. (1996, p. 424) reported that "broken bones of Tertiary soft-shelled turtles are so common on bare hills near the Continental Divide of North America, in south-central Wyoming, that they make up a large part of the pebbles."

The absence of extant trionychids in the northwestern U.S. is intriguing. Given the abundance of turtle fossils, why do we not find more evidence of ancestral trionychids? We presently lack an answer to this question. The early Tertiary Chuckanut Formation specimen provides the first evidence of Trionychid turtles in Washington, and members of this superfamily have not been identified from younger deposits that contain turtle fossils. The extensive semi-tropical fluviatile environments that produced the Chuckanut Formation and correlative deposits offered favorable habitats for many types of aquatic turtles. Indeed, fossil turtles, with their durable and easily recognizable shells, make up the majority of early Tertiary vertebrate discoveries from Washington. The oldest turtle remains reported from Washington are from the Middle Eocene Roslyn Formation, which has yielded carapaces of the chelydridid (snapping turtle) *Acherontemys heckmani* (Hay 1902, 1908) and the dermatemidid pond turtle *Baptemys fluviatilis* (Wheeler 1955). Remains of the giant tortoise *Geochelone* have been found in the Miocene Ellensburg Formation of central Washington (Fry 1973, Gustafson 1978), along with other unidentified turtles (Warren 1941, Smiley 1963, Bryant 1968). Turtles are common fossils at another site in central Washington, the late Pliocene White Bluffs fauna of the Ringold Formation . Taxa include the tortoise, *Testudo* sp. (Merriam and Buwalda 1917, Gustafson 1978), *Clemmys marmorata*, or western pond turtle (Brattstrom and Sturn 1959), and the painted turtle *Chrysemys* sp. (Gustafson 1978). The late Pliocene Taunton fauna of the Ringold Formation has also yielded a diverse turtle assemblage, but unfortunately these specimens have not been described in detail (Morgan and Morgan 1995).

Washington's geologic history provides a foundation for speculating on possible factors that shaped the rise and fall of Trionychid populations. Beginning in the late Eocene the regional climate became cooler and drier and lowland semitropical rain forests were displaced by temperate vegetation. These ecological shifts probably led to profound changes in the flora and fauna, as evidenced by the differences that we observe today in plants and animals from subtropical regions and warm temperate environments. After a prolonged period of geomorphic stability during the early Tertiary, fluvial environments were disrupted by the uplift of the North Cascade Range and by 30 million years ago surface processes were dominated by erosion rather than deposition. Increased volcanic activity may have caused further ecological disruption. The scarcity of animal fossils makes these ancient transitions difficult to reconstruct, however. Perhaps trionychids were one of the organisms that became extinct during the early Tertiary, but the absence of late Tertiary sedimentary rocks in western Washington hinders us from making accurate judgments. In any case, repeated advances of the continental glaciers through the Puget lowlands during the Pleistocene may have caused local extinction of turtles and other aquatic animals. Although various species of pond turtles are abundant in lakes and rivers in central and eastern Washington, these populations may have been re-established during the last 10,000 years from stocks that inhabited non-glaciated regions to the south and east. The North Cascades provide a geographic barrier to the migration of turtles into the northwest part of the state. The present scarcity of trionychids west of the Mississippi Valley suggests that the members of this family disappeared much earlier. In this respect they are reminiscent of trees such as *Platanus* (sycamore) that flourished in the northwest during the early Tertiary, but which survive in North America only in the eastern U.S. Sycamores have been successfully re-introduced in modern times, and in many Washington towns they are one of the most common ornamental trees. Likewise, the Chuckanut trionychid turtle may be an example of an animal family that no longer inhabits the region because of past geologic and climatic events, even though present environmental conditions appear to be hospitable.

Summary

The ventral surface of a turtle carapace preserved in sandstone from the early Tertiary Chuckanut Formation at Bellingham, WA probably belongs to the Superfamily Trionychidae (soft-shelled turtles). Computerized axial tomography of an adjacent bone fragment demonstrates that this fossil likely to be a skeletal remnant from the same animal. The Chuckanut specimen provides the first evidence of trionychids in the Pacific Northwest, but fossilized remains of this group are common in early Tertiary rocks in the northern Rocky Mountain region. Trionychids have not been found in younger rocks of western North America, but other types of turtle fossils are not uncommon. Climatic cooling that began the late Eocene may have caused a restriction in range for turtles, and subsequent mountain building events destroyed many lowland aquatic environments Repeated episodes of continental glaciation during the Pleistocene probably reduced turtle populations even further, and topographic barriers hindered the return of pond-dwelling turtles to their earlier ranges. However, the late Tertiary fossil record from central Washington and the scarcity of extant trionychids west of the Mississippi both suggest that this group disappeared from the northwest long before the onset of Pleistocene glaciation .

Acknowledgements

This paper summarizes the results of investigations initiated by the late Samuel P. Girouard, Jr., an undergraduate paleontology student at the University of Washington at the time of his unexpected death in 1999. Sam wished to thank the following people for their help: Dennis Braman, Donald Brinkman, Philip Currie, Elizabeth Nicholls, and Darren Tanke at the Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, contributed helpful discussions and access to specimens ; Robert Evander provided much hospitality during a visit to the collections of the American Museum of Natural History, New York, and Museum paleontologist Eugene Gaffney reviewed an early version of the manuscript; Glenn Kays at the University of North Dakota shared his knowledge of Cenozoic trionychids. Douglas Clark of Bellingham discovered and later donated the specimen studied in this paper to the Western Washington University Geology Department, where it is presently on display (WWU #00-3-12). Radiology technician Kurt Klucking performed the CT scan at St. Joseph's Hospital Imaging Center in Bellingham.

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