THE CASE FOR FISHING DINOSAURS AT THE ST.GEORGE DINOSAUR DISCOVERY SITE AT JOHNSON FARM

by Andrew R. C. Milner and James I. Kirkland

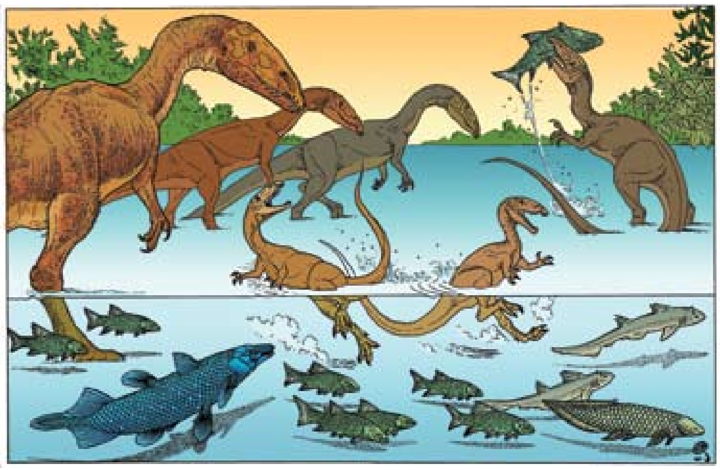


Illustration by Russell Hawley

The St. George Dinosaur Discovery Site at Johnson Farm (SGDS) preserves a world-class collection of dinosaur tracks and associated features. The initial discovery and preliminary scientific interpretation of the site were reported in previous issues of *Survey Notes* (2000, v. 32, no. 3; 2002, v. 34, no. 3). This article summarizes evidence suggesting that dinosaurs at SGDS were feeding on fish.

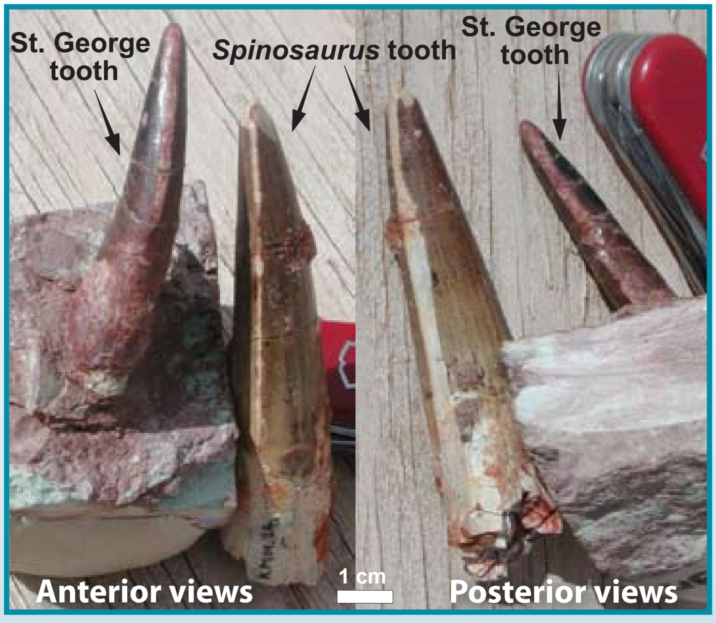
The SGDS preserves not only thousands of dinosaur tracks on at least 25 track-bearing horizons in the basal Jurassic Moenave Formation, but also abundant fish, plant, and invertebrate fossils as well as rare dinosaur teeth and bone. The Moenave Formation at the SGDS provides a window into the earliest Jurassic (about 200–198 million years ago) ecosystem near the margin of a large prehistoric lake—Lake Dixie.

The main track-bearing sandstone near the base of the Whitmore Point Member of the Moenave Formation ("Johnson Farm sandstone bed") preserves casts of dinosaur tracks at its base. This sandstone bed was deposited rapidly on a bed of clay, preserving the fine detail of the clay's surface. Southeast of Riverside Drive at the SGDS museum, the base of this sandstone exposes casts of mud cracks and dinosaur tracks (mostly large *Eubrontes* with smaller, nearly identical *Grallator* type tracks) with isolated scours (flute casts) and diamond-shaped salt casts, suggesting an exposed lake-shore mud flat. Northwest of Riverside Drive, this same surface preserves tool marks, small flute casts, and crescent marks (scratch circles) on an extensively scoured surface; these features indicate relatively strong longshore currents that paralleled the lake shore and exposed mud flat, forming a subaqueous channel. Like in the ocean, longshore currents are created in large lakes by waves obliquely striking the shore.

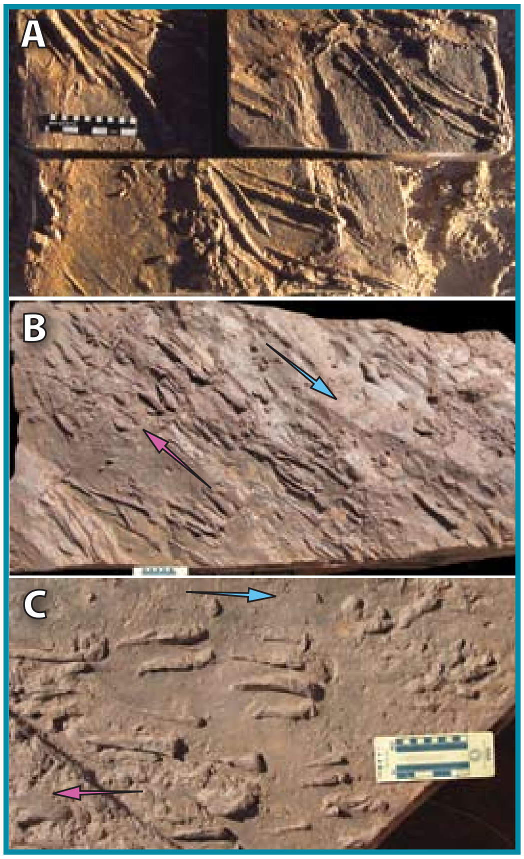
Thanks to the landowners, volunteers, the City of St. George, and critical funding from the State of Utah and the federal government, a museum opened in April 2005 over Shelden Johnson's initial discovery site south of Riverside Drive.

Among the most exciting discoveries at SGDS is an abundance of dinosaur swim tracks (known by the name *Characichnos*) at the base of the thickened "Johnson Farm sandstone bed" northwest of Riverside Drive representing the subaqueous channel. Here, the SGDS has the world's largest and best-preserved collection of dinosaur swim tracks, which resolves a long-standing controversy among paleontologists about the very existence of swim tracks. Part of the controversy revolved around the simple fact that if a dinosaur were swimming fully buoyed up in the water, it would not leave marks on the bottom. Swim tracks of meat-eating dinosaurs are typically arranged in sets of three parallel scrape marks that taper at each end, with the longer middle toe leaving a longer and deeper scrape mark compared to the shorter outer toes.

Most, but not all, of the swim tracks are comparable in size to the smaller walking track *Grallator*, which here is indistinguishable from small-scale versions of *Eubrontes*. The vast majority of these



Large theropod teeth from SGDS vs. Spinosaurus *from North Africa.*



(A) Initial swim track blocks discovered by A.R.C. Milner in 2001. (B and C) Examples of swim tracks from Washington County School District Quarry #1. Red arrows indicate swim direction, blue arrows indicate current direction.

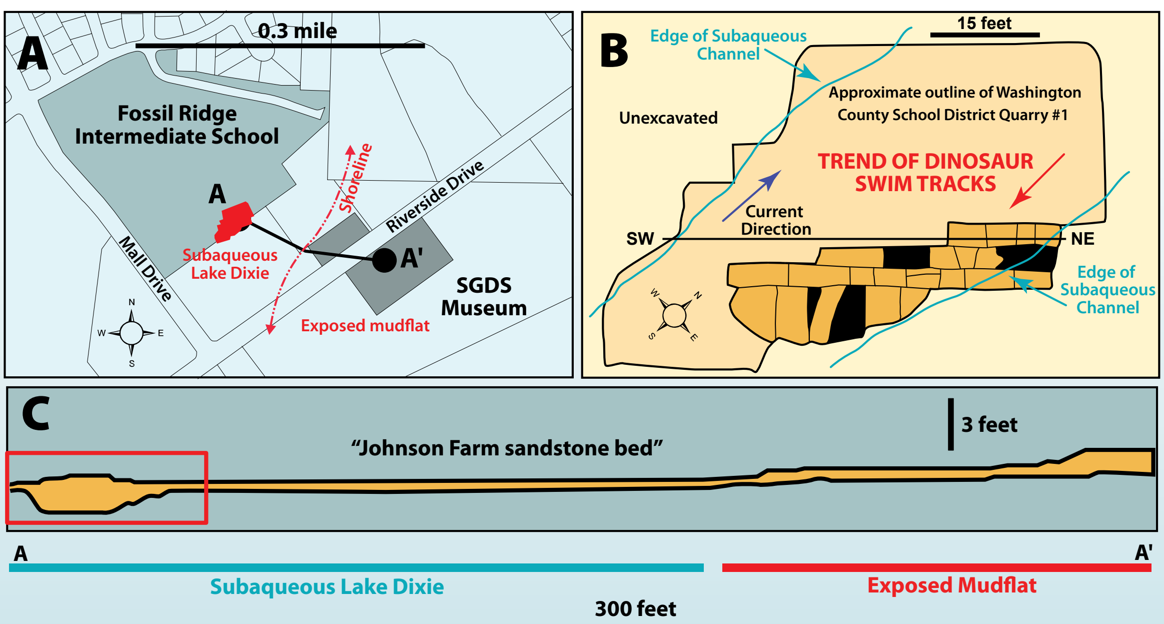
swim tracks are oriented in the opposite direction from the current indicators in the channel. The most likely scenario is that numerous meat-eating dinosaurs were wading in the shallows of the lake and stepped off into the deeper subaqueous channel, where the smaller dinosaurs were swept off their feet, resulting in the dinosaurs floundering in the water against the strong current.

The abundance of swim tracks leads to the obvious question: Why were so many dinosaurs wading hip deep in the lake? It is certainly a lot harder to walk through water than to walk along a beach.

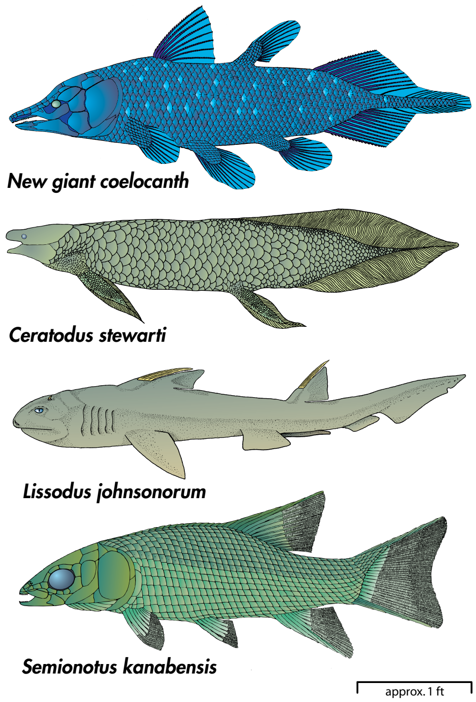
Many fish remains have been recovered at the SGDS from higher in the Whitmore Point Member. This, along with sedimentological data, indicates that after the top of the "Johnson Farm sandstone bed" was deposited, Lake Dixie deepened and expanded across the area to an eventual maximum extent north of Cedar City and Zion National Park and east to Kanab. How far Lake Dixie extended south into Arizona and west into Nevada is unknown.

Many of the fish preserved in the Whitmore Point Member are large and include two new species we named in 2006: the hybodont (spiny, freshwater) shark *Lissodus johnsonorum* and the lungfish *Ceratodus stewarti*, both about 3-4 feet long. Other fish include a large coelacanth (lobe-fined fish) similar to *Chinlea* (about 6 feet long) and abundant semionotid fish as much as 4 feet long, probably all belonging to the genus *Semionotus*. *Semionotus* was shaped like a modern carp, but completely covered in a "chain mail" armor of heavy, enamel-covered, diamond-shaped scales (ganoid scales) like the modern gar of the southeastern United States. The abundance of large fish lends additional support to the hypothesis that Lake Dixie was a very large lake.

The larger dinosaur teeth recovered from the SGDS are almost certainly from the theropod dinosaur that made the *Eubrontes* tracks. A well-preserved thoracic vertebra from the SGDS suggests the dinosaur may have been a relative of the double-crested theropod *Dilophosaurus*, which is known from several specimens in the overlying Kayenta Formation, where hundreds of *Eubrontes* tracksites are documented. The large SGDS teeth are tall, slender, and typically cylindrical, exhibiting a distinct wear pattern in which the serrated ridges (carinae) along the front and back margins of the teeth are worn from the tip down to the base. We hypothesized this may be from the enamel-on-enamel wear produced by these dinosaurs biting through the "chain mail"-covered semionotids. Spinosaurid teeth from the



(A) Area of the SGDS showing location of Lake Dixie shoreline just prior to deposition of the "Johnson Farm sandstone bed." Red area indicates location of Washington County School District Quarry #1, where the swim track blocks were excavated. Cross section A–A' shown in C. (B) Map of area of Washington County School District Quarry with orange indicating mapped blocks and black areas representing missing blocks. Line labeled SW–NE indicates cross section within red box in C. (C) Cross section showing relative change in thickness of "Johnson Farm sandstone bed." Red box indicates area shown in B.



Reconstructions of larger fossil fish from SGDS.

Andrew R.C. Milner (right) is the City Paleontologist and Curator at the St. George Dinosaur Discovery Site at Johnson Farm in St. George, Utah. His research primarily includes vertebrate tracks and fossil fishes of the Mesozoic, particularly the Late Triassic and Early Jurassic. Andrew studied late Pleistocene Champlain Sea fossils in eastern Canada for the Canadian Museum of Nature in Ottawa, and spent five seasons working on the Middle Cambrian Burgess Shale in Yoho National Park, British Columbia, Canada, for the Royal Ontario Museum (Toronto, Ontario).

Dr. Jim Kirkland (left) is the Utah State Paleontologist with the Utah Geological Survey. An expert on the Mesozoic, he has spent more than 30 years excavating fossils across the southwestern U.S. and Mexico, and has authored and co-authored more than 75 professional papers. The reconstruction of ancient marine and terrestrial environments, biostratigraphy, paleoecology, and mass extinctions are some of his interests. He has discovered and described numerous new dinosaurs including several armored and horned dinosaurs, and several meat-eating dinosaurs of which the giant dromaeosaur *Utahraptor* is the best known. He has also described and named many fossil mollusks and fish.

Early Cretaceous of North Africa are similar and display the same sort of distinctive wear pattern. Spinosaurids are thought to have fed to a significant degree on fish, as indicated by their crocodile-like skulls. The huge semionotid *Lepidotes* is commonly preserved in the same environments with spinosaurid remains, suggesting that this type of tooth wear is a result of eating fish covered in heavy, enamel-covered scales.

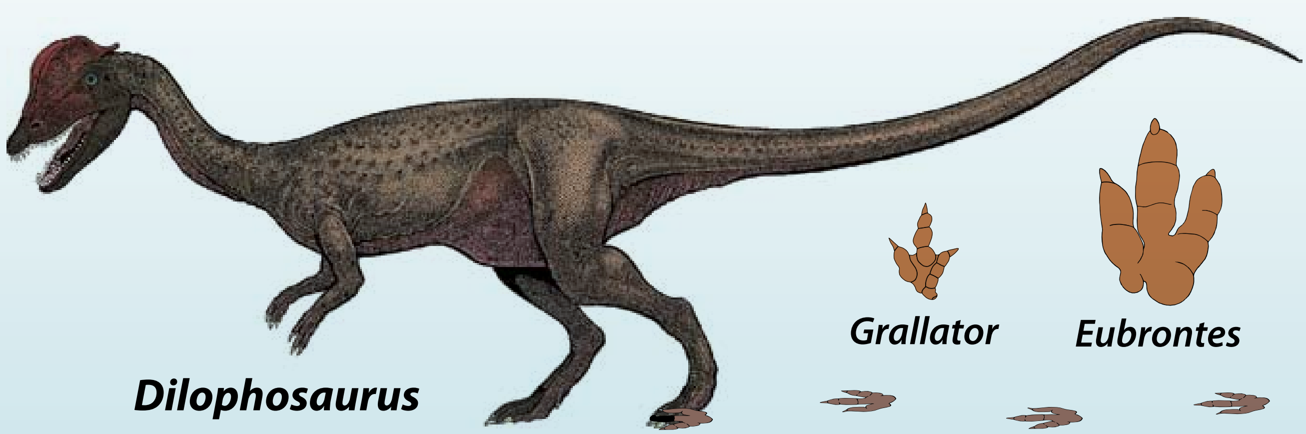
Dilophosaurus exhibits a few features that suggest fish-eating behavior:

1) The ends of the jaws are expanded laterally to form an interlocking rosette of long teeth at the front of the jaws. Spinosaurids have a similar feature, which is well developed in the Indian gharial—the most fish-eating of all modern crocodilians.

2) Unlike other meat-eating dinosaurs, *Dilophosaurus'* nasal openings are retracted back from the front of the jaws. Spinosaurid nasal openings are even more extremely retracted. This characteristic may have limited the splashing of water into their nostrils while fishing.

3) Both *Dilophosaurus* and spinosaurids have relatively long arms, which, with their well-developed claws, may have helped them catch fish.

Finally, the Triassic-Jurassic boundary has been proposed to fall within the Moenave Formation. Dramatic faunal turnover has been proposed for the Late Triassic and, whether as a period of more rapid faunal loss than normal or a mass extinction, the subsequent earliest Jurassic was a very different and apparently more impoverished world biologically. The abundance of large fish in Lake Dixie would have provided an important source of protein in this post-cataclysmic world.



Reconstruction of Dilophosaurus *from the Kayenta Formation with the Eubrontes and Grallator track types. Illustration by Brad Wolverton.*