tooth morphology, and dentary-squamosal joint. Four genera are commonly included in the family Tritheledontidae. *Diarthrognathus*, *Tritheledon*, and *Pachygenelus* are known from the Red Beds and Cave Sandstone (Stormberg Group) of South Africa and Lesotho. There is a problem with the age of these formations, ranging from Late Triassic (*2*) to Early Jurassic (*9*). *Chaliminia* is recorded from the Los Colorados Formation of Argentina. *Pachygenelus* now appears in the Dockum Group of Texas.

Bonaparte (*10*) recognized two separate lineages, here considered as subfamilies among the ictidosaurs: Tritheledontinae (containing *Tritheledon* and *Diarthrognathus*), with transversely widened postcanines and a complex occlusion of the crowns; and Pachygenelinae (containing *Pachygenelus* and *Chaliminia*) with narrow postcanines and scissor-like occlusion.

Bonaparte and Barberena (*11*) described *Therioherpeton*, an interesting small cynodont of uncertain familial affinity, from the upper Middle or lower Upper Triassic Santa Maria Formation of Brazil. They identified such ictidosaurian cranial characters as a lack of postorbital bar, weak zygomatic arch, and wide braincase. The postcanines are four-cusped sectorial teeth with bifurcated root, otherwise similar to *Pachygenelus*. Since *Pachygenelus* tooth morphology was unknown at the time, they could not determine the systematic position of *Therioherpeton*. *Therioherpeton* is included here within Pachygenelinae, and its suggested relationship is shown in Fig. 2.

Although the continental drift theory has triumphed in recent years, many details are uncertain. There is a long-standing debate whether there were two unconnected supercontinents, Laurasia and Gondwana, or one supercontinent, Pangea, at the beginning of the Mesozoic. The discovery of an ictidosaur from Texas adds to the growing list of reptilian groups occurring in both North America and Gondwana in the Late Triassic and supports the concept of Pangea, which was probably still intact during the Late Triassic to Early Jurassic time. This is also reflected by the uniform fauna over most of the world such as rhynchosaurids, plateosaurids, morganucodontids, protosuchids, traversodontids, and tritylodontids. There may have been few impediments to tetrapod migration through Pangea.

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Early Tertiary Age of Pitchstone in the Northern Black Hills, South Dakota

Abstract. *A block of pitchstone in the northern Black Hills, South Dakota, is Paleocene in age, according to potassium-argon dating of biotite and fission-track dating of zircon in the sample. These data invalidate published suggestions that the age is much younger. The pitchstone is not extrusive in its present position but instead is in a volcanic pipe with other fragments that came downward from as much as 1100 meters above the modern surface.*

An isolated small outcrop of pitchstone adjacent to the Tomahawk golf course, 10 km south-southeast of the city of Deadwood, has caused differences in interpreting the Cenozoic history of the northern Black Hills, South Dakota. Field evidence and numerous age determinations on intrusive rocks indicate an early Tertiary age for most or all of the igneous activity of the region, but a whole-rock potassium-argon age of 10.5×10^6 years for this pitchstone led Kirchner (*1*) to suggest that there was also a much younger period of volcanism. New potassium-argon age data on biotite and fission-track dating of zircon show the pitchstone to be 56×10^6 years old, which places it in early Tertiary time. This age is in accord with field relations indicating that the pitchstone and associated rocks are subsided material in a volcanic neck that originally penetrated approximately 1 km of cover.

The pitchstone (called obsidian by most earlier investigators) forms a single block, less than 10 m long, on a knoll underlain by bedded lithic tuffs and various volcanogenic clastic rocks. The volcanic assemblage extends over an elliptical area about 1600 by 800 m that is surrounded mostly by Precambrian schists but also is in contact with a tilted block of the Cambrian Deadwood Formation and with Tertiary rhyolite porphyry. Outcrops in the area are sparse.

The locality is near the southern edge of a belt of intrusions that crosses the northern Black Hills in a west-northwest direction. Compositions are mostly rhyolitic or monzonitic. Age determinations range from about 40×10^6 to 60×10^6 years (*1*).

After finding well-preserved biotite phenocrysts and sparse zircon in a small sample, we collected 70 kg of the pitchstone. In addition to glass, the rock contains gray, very fine-grained crystalline material in veinlets and layers that probably is highly altered obsidian but may be partly original. This material could be only partially excluded from the field sample. In thin sections of rock without megascopically visible alteration products, the glass is isotropic but has tiny anisotropic particles. Some of these particles are individual grains distributed through the glass, but most are in aggregates and veinlets that apparently represent devitrification. The rock also has phenocrysts of biotite with dimensions of as much as 0.4 by 0.7 mm and phenocrysts of plagioclase as much as 2 mm in diameter. A rim of devitrified glass surrounds some of the phenocrysts.

Biotite, glass, and zircon separates were prepared by standard methods. The glass was purified by use of both heavy liquids and an isodynamic magnetic separator to remove altered material. An analysis of the purified glass showed approximately 7.5 percent H_2O. Conventional age-determination techniques were used.

Potassium-argon age determinations ($\pm 2\sigma$) yielded $(55.8 \pm 1.4) \times 10^6$ years for the biotite and $(24.8 \pm 0.8) \times 10^6$ years for the glass. These ages are based

on the following experimental data for the obsidian and biotite, respectively: 3.24 and 6.80 percent potassium; 1.400×10^{-10} and 6.675×10^{-10} mole of radiogenic ^{40}Ar per gram; 50.1 and 87.7 percent radiogenic argon (the decay constants for ^{40}K are as follows: $^{40}K/K = 1.167 \times 10^{-2}$ atom percent; $\lambda_\beta = 4.962 \times 10^{-10}$ year $^{-1}$; $\lambda_{\epsilon + \epsilon'} = 0.581 \times 10^{-10}$ year $^{-1}$). The considerable hydration of the glass indicates a probable loss of argon, which would make the apparent age of the glass too young. Kirchner's even lower age probably indicates that his whole-rock sample was more altered than our purified glass. The age of the biotite is the probable age of the rock. The biotite would yield too great an age if it contains excess radiogenic argon, but a fission-track age ($\pm 2\sigma$) for zircon of $(60.5 \pm 8.8) \times 10^6$ years excludes this possibility. This age is based on the following data: fossil density of 12.57×10^6 tracks per square centimeter; 640 fossil tracks counted; induced density of 10.30×10^6 tracks per square centimeter; 261 induced tracks counted; neutron dose of 0.828×10^{15} cm^{-2}; and a uranium content of 390 parts per million (the fission decay constant for ^{238}U is 7.03×10^{-17} year^{-1}). The analytical uncertainty of the fission-track age is large because only three zircon grains were suitable for use; in other zircons the fossil-track density is too great for counting or the uranium distribution is too complexly zoned.

We regard the age of the rock as 56×10^6 years on the basis of the potassium-argon data for biotite and confirmation by the fission-track results for zircon. This age is near the end of the Paleocene and within the range (40×10^6 to 60×10^6 years) of age determinations for the Tertiary intrusions of the Black Hills.

The late Paleocene age removes longstanding uncertainty about how to explain the geology of the Tomahawk locality. In a 1912 publication Darton (*2*) regarded the assemblage as a remnant of a volcano formed in Oligocene time on the Oligocene erosion surface. He said (*2*, p. 603) the Black Hills "may have been the source of part if not all" of the volcanic ash in the widespread Oligocene deposits to the east and southeast. In 1925, Darton and Paige (*3*) changed the age to Quaternary(?) but without giving a reason. Darton and Paige showed (*3*) that the Black Hills had much the same topography in the Oligocene as today. The evidence is the existence of outliers of sediments of the White River Group (Oligocene) in many places on all older rocks. Some are near the bottom of present-day valleys. Darton and Paige described White River outliers that they regarded as remnants of a mantle that once extended for many kilometers across the region north of the Tomahawk locality. Because the edge of a rather large remnant of this mantle is 0.5 km east of the Tomahawk assemblage, the Tomahawk area must have been exposed to erosion by Oligocene time. Later, Noble suggested (*4*, p. 930) that the volcanics were the last product of the early Tertiary igneous activity and the assemblage "probably rests on and is contemporaneous with Oligocene gravel deposits and an Oligocene erosion surface."

An important advance came when Runner (*5*) interpreted the Tomahawk assemblage as a volcanic breccia pipe. In the breccia he found fragments of fossiliferous Upper Cretaceous Carlile shale. The Carlile is about 1100 m stratigraphically above the Precambrian surface, and the nearest outcrop now is 25 km to the northeast beyond the edge of the Black Hills. Runner proposed that a volcanic pipe had penetrated to the surface, and later the magma column withdrew and the breccia fragments subsided to their present level. He did not mention the pitchstone, nor did he say anything about the age of the event except that it was post-Carlile. His evidence puts it in pre–White River time before the Cretaceous cover had been stripped from the central Black Hills and thus makes it a part of the early Tertiary igneous activity.

Drake (*6*) said the age is probably Eocene. He mapped most of the volcanics as rhyolitic lithic tuff, which in his view accumulated in a thick pile that was cut by vent breccia pipes. One of the breccia pipes contained the pitchstone, which he believed had solidified "at the surface on top of the vent breccia" (*6*, p. xiii). Drake supposed that the Carlile shale fragments had been acquired from steep cliffs 1000 m high surrounding the volcano. Subsequently a cylindrical block was downdropped a short distance, bringing the Carlile fragments to their present level. A gravimetric traverse by Drake showed a gravity low that he interpreted as caused by the neck of the volcano. Additional traverses by Roggenthen (*7*) confirm the existence of this gravity low.

Kirchner reported his pitchstone whole-rock sample as 10.5×10^6 years old (*1*). His purpose was to report this as the youngest igneous activity recognized in the Black Hills or nearby areas. Kirchner described the pitchstone as a xenolith in rhyolite flow breccia, which he assumed to be extrusive on the present surface. Later, Kirchner (*8*) suggested that the assemblage originated as tuffs, mudflows, and flow breccias from a distant volcanic source.

Runner's proposal best fits the Late Paleocene age of the pitchstone and the general geology of the area. That is, the present rock assemblage represents the subsided filling of a volcanic neck that originally penetrated at least 1000 m of overlying sedimentary rocks at an early stage in the development of the Black Hills. Drake also called on subsidence, but, unlike Runner, he thought the volcanic rocks originated not far above their present level and did so in a region of extraordinarily rugged topography. The other interpretations of the structure and age, not just by Kirchner (*1, 8*) but also by Darton (*2*), Darton and Paige (*3*), and Noble (*4*), imply an assumption that, because some of the rocks have extrusive components, they must have been extruded in the place where they now are. The Carlile may well have been at or near the surface 56×10^6 years ago and slumped readily into the pipe during the time before subsidence. The other rocks of the Tomahawk assemblage, especially the pitchstone, together with the Paleocene age, demonstrate that the early Tertiary igneous activity of the northern Black Hills included volcanism.

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