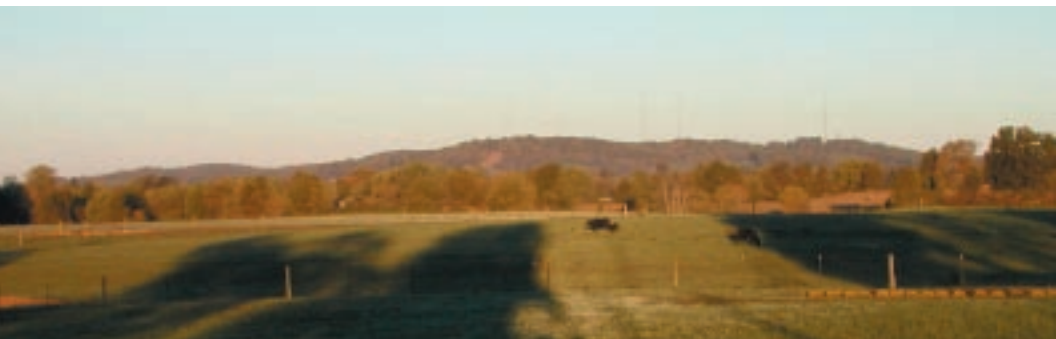


**42nd Annual Meeting of
the American Institute of
Professional Geologists
“Geologic Information: Racing
into the Digital Age”**



**The Jephtha Knob
Cryptoexplosive Structure,
Shelby County, Kentucky,
and
Buffalo Trace Distillery,
Franklin County, Kentucky**

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**Hosted by
Kentucky Section of the American Institute of
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October 8–13, 2005

Radisson Plaza Hotel

Lexington, Kentucky

2005

**American Institute of Professional Geologists
2005 Annual Meeting
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The Jephtha Knob Cryptoexplosive Structure, Shelby County, Kentucky, and Buffalo Trace Distillery, Franklin County, Kentucky

Mark F. Thompson

Abstract

This half-day trip is divided into two parts. First we will examine a Bluegrass bourbon distillery, followed by a westward excursion to examine the geology and geomorphology of a suspected impact structure. Our first stop will be a guided tour of the Buffalo Trace Distillery in Frankfort, Ky. This will occupy our entire morning. In the afternoon we will make six stops in the vicinity of the Jephtha Knob structure in eastern Shelby County, Ky. Our Jephtha Knob stops will provide opportunities to discuss regional versus local geology, the effects of impacts on carbonate target rocks, and the geomorphic evolution of this structure.

Introduction

Many scientists today suspect that the Jephtha Knob structure (Fig. 1) is an impact structure. It is not listed with the more than 170 such places on Earth because many of the accepted criteria required to define impact structures have not been observed at Jephtha Knob. Ever since W.M. Linney mentioned Jephtha Knob in his 1887 geologic report (its first appearance in scientific literature), the interpretation of its origin has been a dynamic one, even to this day.

Jephtha Knob contains an eroded and buried remnant of a structure that is undergoing a second cycle of erosion. After deposition and lithification of the Middle and Late Ordovician shallow marine carbonates, the Jephtha Knob event occurred, forming a structure that was subjected to subaerial weathering processes during Late Ordovician to Early Silurian time. A Silurian transgression resulted in carbonate deposition (Brassfield Formation), which buried the

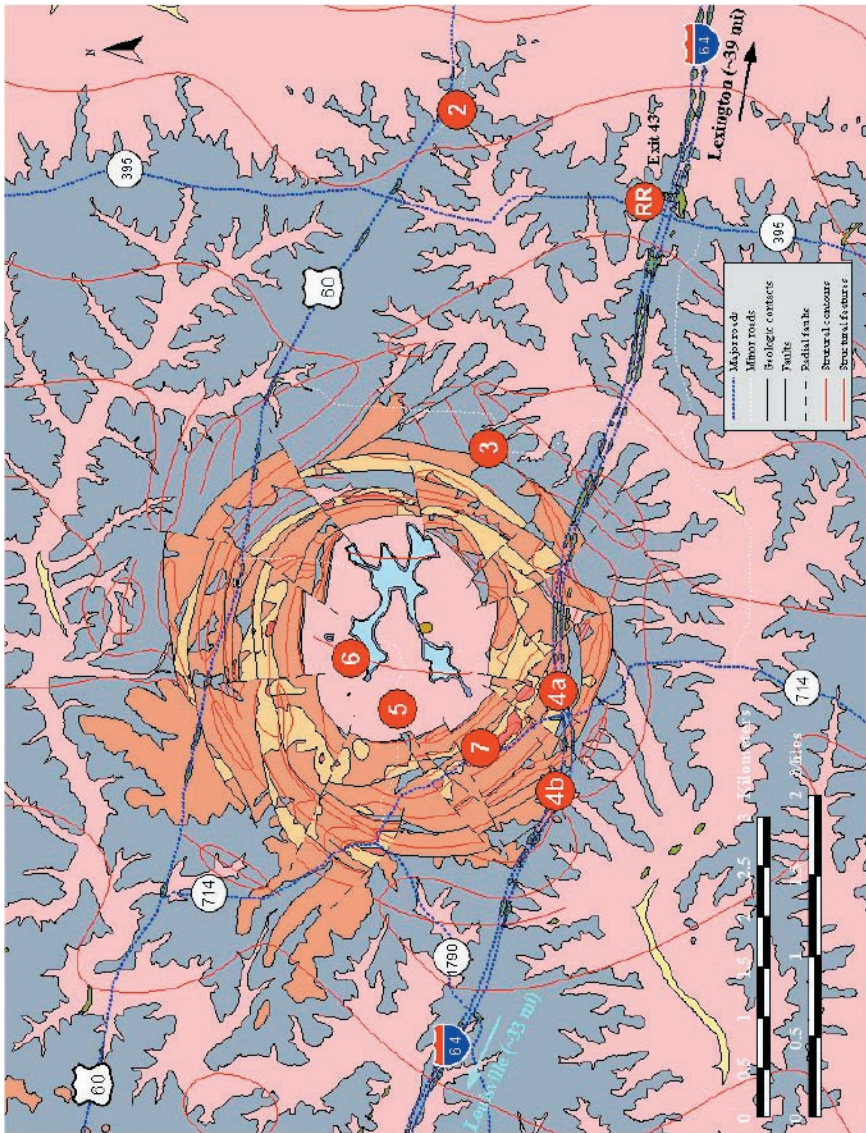


Figure 1. Geologic map of Jephtha Knob showing local roads and locations of field trip stops (adapted from trip leader's field map).

structure. Today, within the second cycle of erosion, much of the Jephtha Knob structure has been eroded down an additional 220 to 320 feet below the level of the Ordovician-Silurian contact (Fig. 2). As a result of erosion and a thick soil cover, only sparse rock crops out at Jephtha Knob.

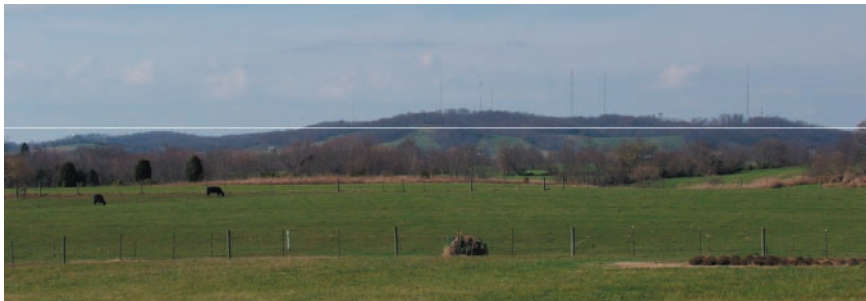


Figure 2. Westward view of Jephtha Knob from 3 miles away. Horizontal line represents the approximate Ordovician-Silurian contact.

The Jephtha Knob structure is a nearly circular (approximately 3 miles in diameter) area of uplifted, intensely faulted and folded, Middle to Late Ordovician, shallow marine carbonate rocks (Fig. 3). Jephtha Knob is situated about 50 miles west of the axis of the Cincinnati Arch and nearly 50 miles north of the 38th Parallel Lineament of Heyl (1972) (Fig. 4).

Previous Scientific Investigations

The Jephtha Knob structure was first reported by William M. Linney (1887) of the Kentucky Geological Survey. Linney discovered localized faulting in the Jephtha Knob area and suggested that the structure was produced by localized subsidence and subsequent infilling of sediment. Walter H. Bucher (1925) produced the first geologic map of Jephtha Knob, based primarily on biostratigraphy, and suggested it had a cryptovolcanic origin. During the construction of Interstate 64 in eastern Shelby County, Willard Rouse Jillson (1962) discovered three previously unmapped faulted disturbances south of Jephtha Knob.

C. Ronald Seeger (1968) studied Jephtha Knob and performed geophysical work (gravity and magnetic surveys). His magnetic survey showed that a basement counterpart to the Jephtha Knob structure is unlikely because deformation essentially disappears 700 feet below the present surface of Jephtha Knob, leaving the crystalline basement rocks 5,500 feet below the present surface unaffected. From this and many other findings, Seeger concluded an exogenetic origin for Jephtha Knob, hypervelocity impact from a bolide being the most likely mechanism. Seeger failed to provide confirming evidence of unquestionable criteria for his impact hypothesis, however.

SYSTEM	SERIES	GROUP, FORMATION, MEMBER Heavy line to left of column marks units that crop out in structure	THICKNESS, IN FEET	DESCRIPTION
SILURIAN	Middle	Louisville Limestone Waldron Shale Laurel Dolomite Osgood Formation	75	Concealed by soil and chert residuum. Presence inferred from fossils identified in residuum (Foerste, 1931, p. 182) and from thickness of interval
	Lower	Brassfield Formation	18	Finely crystalline calcareous dolomite; contains abundant small vugs; angular fragments of very finely crystalline dolomite present in some beds; basal 3 to 6 ft. in several localities is calcarenite and calcirudite consisting largely of fragments reworked from Upper Ordovician formations
ORDOVICIAN	Upper	Drakes Formation	25-50	Nodular-bedded fossiliferous limestone and shale
		Bardstown Member Rowland Member	50	Argillaceous, dolomitic limestone
	Grant Lake Limestone	140	Nodular-bedded fossiliferous limestone and shale	
	Calloway Creek Limestone	60	Fossiliferous limestone and minor interbedded shale; 6-8 ft. thick calcarenite at top	
	Clays Ferry Formation	300	Interbedded limestone and shale	
Middle	Lexington Limestone	200	Fossiliferous limestone Calcilutite Calcarenite Fossiliferous limestone Brachiopod coquina, calcilutite, and shale; 24-56 ft. above base of formation. Calcarenite	

Figure 3. Stratigraphic section at Jephtha Knob. Thickness and presence of members based on regional thickness and facies trends (from Cressman, 1981).

Earle R. Cressman mapped the Jephtha Knob structure on the basis of lithostratigraphy and produced the most detailed geologic maps of the structure in existence today (Cressman, 1975a, b). His

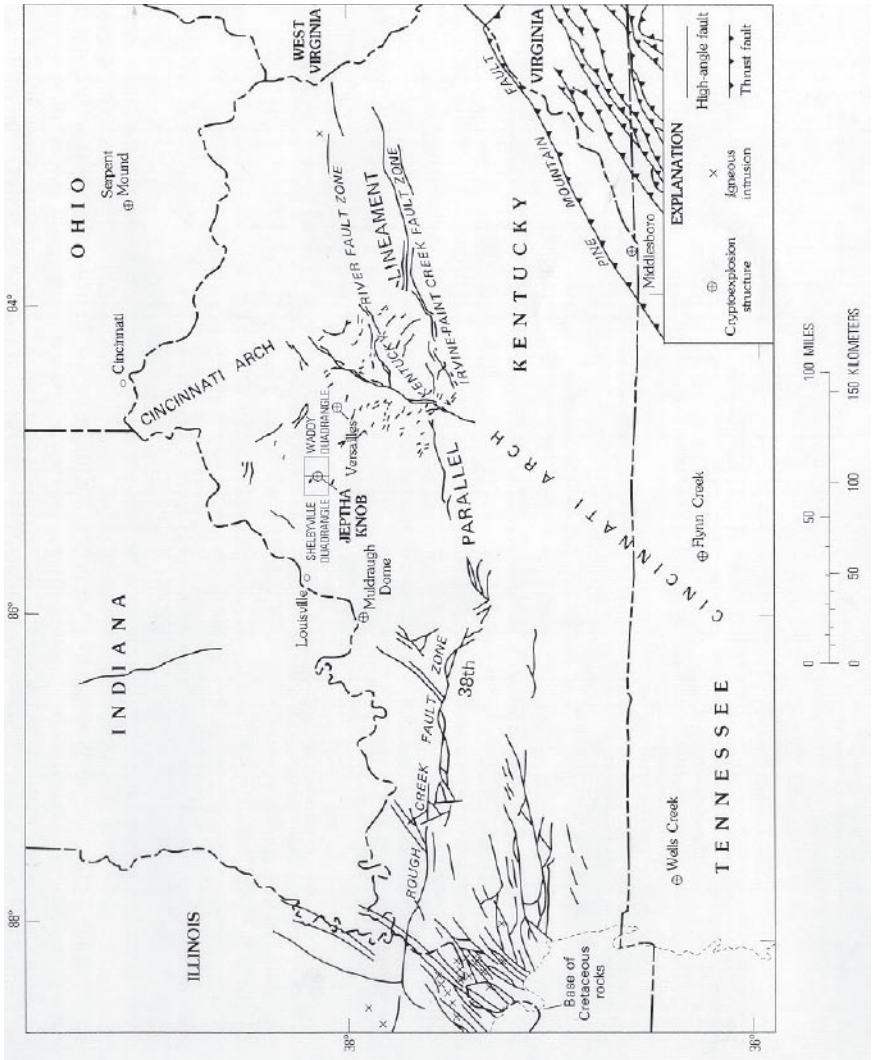


Figure 4. Map showing the structural features of Kentucky and parts of adjacent States (from Cressman, 1981).

maps show a cap rock, a central core of uplifted material, and a belt of faults and a belt of folds. The fault belt consists of radially propagating faults, several listric normal faults ringing the structure, and three reverse faults in contact with the central core of uplifted material (Cressman, 1981).

Seeger and others (1985) conducted an iridium survey in the vicinity of Jephtha Knob. They analyzed and compared samples col-

lected from the highest breccia occurrences at Jephtha Knob, within the basal Brassfield Formation, with other breccias found there. The basal Brassfield Formation breccias yielded anomalously high levels of iridium (0.094 to 0.122 ppb). Such small amounts of iridium may merely represent iridium that fell upon Earth during Ordovician-Silurian lacunae, only to be reworked and concentrated in lag deposits during Silurian transgression. Nevertheless, Seeger and others' (1985) survey may be worthy of further investigation by incorporating the Silurian rocks, which crop out approximately 19 miles west, into this survey. Detecting such low levels of iridium requires advanced techniques, instrumentation, and analytical experience, which only a handful of laboratories worldwide can provide (Montanari and Koberl, 2000, Koberl, personal communication, University of Vienna, 2005). Before his untimely death in 1980, Dr. Seeger was investigating the possibility that this structure is the central peak of a much larger complex crater (Seeger, 1986).

Carbonate Impact Targets

The shock metamorphic effects on sedimentary targets, especially carbonates, are a relatively new frontier in impact geology. There are no definitive microscopic impact criteria for carbonate rocks at this time (Bevan M. French, personal communication, Smithsonian Institution, 2005). Much of today's impact criteria are derived from studies performed on targets composed mostly of crystalline rocks (e.g., Sudbury, Ries, and Vredefort).

Gordon R. Osinski, J.G. Spray, Pascal Lee, and others are examining sedimentary targets with a fresh emphasis on carbonates. It has been widely held that sedimentary targets decompose during high temperatures as they release enormous quantities of H_2O and CO_2 during impact, and therefore deduced that they contain approximately two orders of magnitude less melt rock than crystalline targets do. The work of these gentlemen is proving otherwise. In short, during abnormally high pressures that occur during impact, carbonate rocks do not behave as has been widely held. Carbonates may instead melt, break up as diverse breccias, and, in some cases, flow as a fluidized mass. These scientists have determined the clast-to-melt ratio of carbonates to be nearly equivalent to coherent impact melt sheets found in crystalline targets (Osinski and others, 2002a, b).

Conditions are not normal during impact events (Fig. 5). The rapid release of large amounts of energy in such events puts too

Characteristic	Regional and Contact Metamorphism; Igneous Petrogenesis	Shock Metamorphism
Geological setting	Widespread horizontal and vertical regions of Earth's crust, typically to depths of 10–50 km	Surface or near-surface regions of Earth's crust
Pressures	Typically <1–3 GPa	100–400 GPa near impact point; 10–60 GPa in large volumes of surrounding rock
Temperatures	Generally $\leq 1000^\circ\text{C}$	Up to $10,000^\circ\text{C}$ near impact point (vaporization); typically from 500° to 3000°C in much of surrounding rock
Strain rates	$10^{-3}/\text{s}$ to $10^{-6}/\text{s}$	$10^4/\text{s}$ to $10^6/\text{s}$
Time for completion of process	From 10^6 – 10^7 yr	"Instantaneous": Shock-wave passage through 10-cm distance, $<10^{-5}$ s; formation of large (100-km-diameter) structure <1 hr
Reaction times	Slow; minerals closely approach equilibrium	Rapid; abundant quenching and preservation of metastable minerals and glasses

Figure 5. Shock metamorphism from Impacts: Distinction from other geological processes (from French, 1998).

much sudden stress on the target rocks for them to respond in the normal way. Typical impact velocities of tens of kilometers per second far exceed the velocities of sound in the target rocks (typically 3 to 5 miles/second). The resulting impact-produced shock waves travel through the target rocks at supersonic velocities, and they impose intense stresses on the rocks without giving them time to give way by normal deformation. In the shock-wave environment, transient pressures may exceed 500 gigapascals (GPa) at the impact point, and may be as high as 10 to 50 GPa throughout large volumes of the surrounding target rock. Transient strain rates may reach seven to 12 orders of magnitude higher than those in ordinary geological processes. At the higher shock pressures (≥ 60 GPa), shock-produced temperatures can exceed 2000°C , and rapid, large-scale melting occurs immediately after the shock wave has passed (French, 1998).

Part 1: A Bluegrass Bourbon Distillery

Begin at the Radisson hotel and proceed northwest on West Main Street for 0.4 mile. Turn right onto Newtown Pike. Continue traveling Newtown Pike for 3.3 miles and then merge onto I-64 West toward Louisville. Continue west on I-64 for 19.1 miles, then take exit 58. Make a right and travel 2.5 miles north on U.S. 60 until it becomes U.S. 127/U.S. 421. Go straight for another 2.5 miles while following the signs to the Civic Center and downtown. Do

not make any turns until you see the Buffalo Trace Distillery on the right.

Stop 1: Buffalo Trace Distillery, Frankfort, Ky.

Our first stop is the Buffalo Trace Distillery, which stands as America's oldest distilling site, located on an ancient buffalo crossing where the state's first settlement north of the Kentucky River was surveyed in 1773. Buffalo Trace Kentucky Straight Bourbon Whiskey has been developed to be the distillery's flagship bourbon and to reflect the history and heritage that are unique to Buffalo Trace Distillery.

At this stop we will receive a complimentary guided tour of the distillery. Afterwards we may visit their gift shop, collect our boxed lunches, and travel onward to stop 2.

Part 2: The Jephtha Knob Structure

From the Buffalo Trace Distillery, turn right onto U.S. 127S/ U.S. 421N and continue for 0.9 mile. Turn right onto U.S. 60 and travel west for 8.8 miles. Make a left onto Peytona Beach Road and continue for 0.5 mile. Stop 2 is on the left side of the road.

Stop 2: Panoramic view of the Jephtha Knob Structure (world geodetic survey [WGS] 84 datum, N 38.17258716, W 85.05705901, elevation 910 feet)*

Stop 2 is a westward view of the Jephtha Knob Structure. We are standing 3.25 miles east from the center of this structure. In the distant foreground, 2.5 miles away, is an outer arcuate belt of knobs (Figs. 2, 6). This eastern arcuate belt is approximately 1.7 miles long and trends north-south. Weathering processes on this complexly folded and faulted structure have characterized this outer arcuate belt of knobs with a pseudo-flatiron appearance. The occurrence of resistant rocks of the Drakes Formation situated in deeper, down-dropped fault blocks relative to the other surrounding fault blocks is the cause for the development of this arcuate knob belt. There may once have been another arcuate belt of knobs approximately 0.25 mile east of these and possibly many others throughout Jephtha Knob's geomorphic history. An imaginary line drawn in a horizon-

*Latitude/longitude measured in decimal degrees.

