National Park Service
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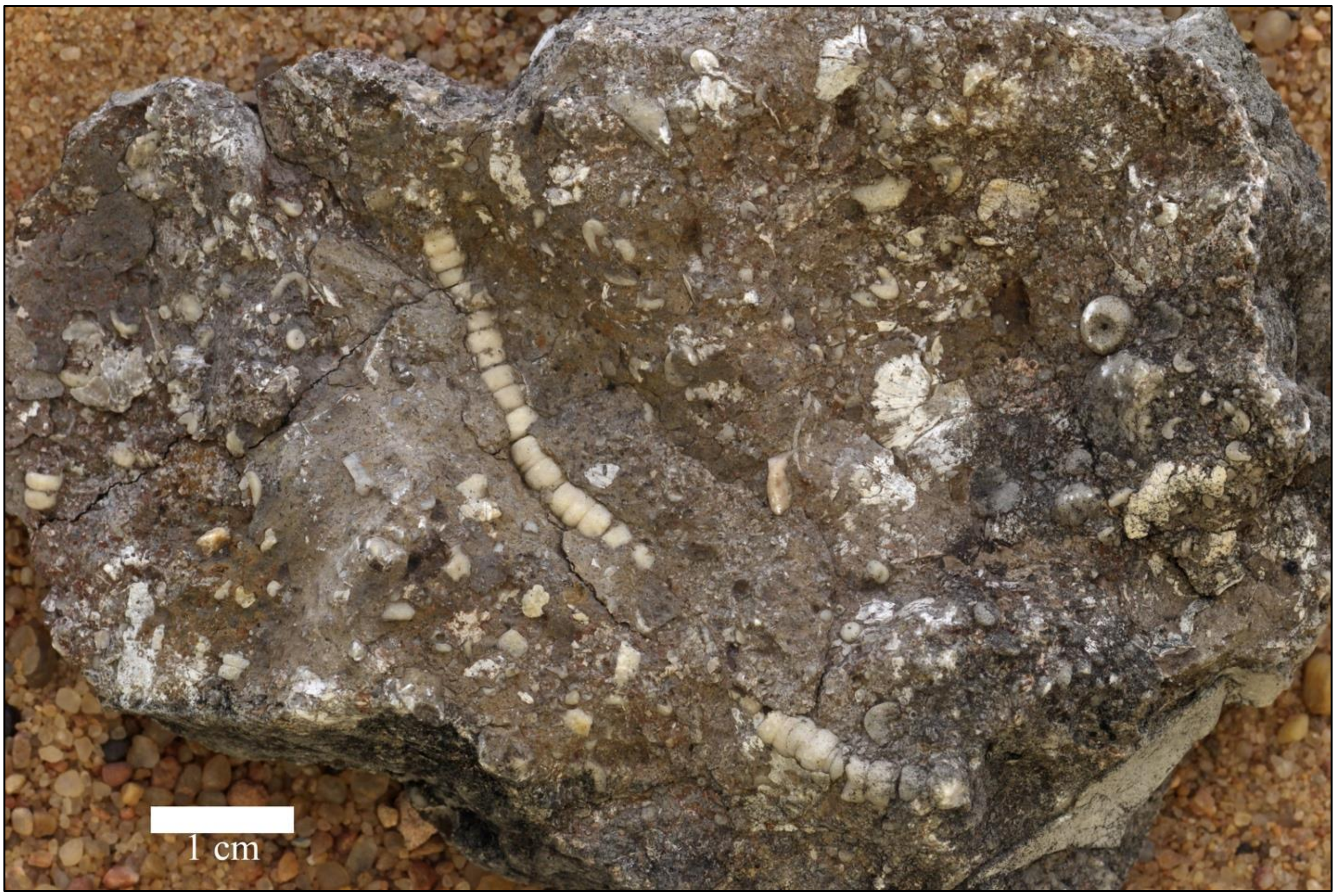
Natural Resource Stewardship and Science

Chickasaw National Recreation Area

Paleontological Resources Inventory (Public Version)

Natural Resource Report NPS/CHIC/NRR—2016/1276



ON THE COVER

Echinoderm stalk and columnals collected from the Welling Formation at the "Veterans Lake" echinoderm locality. Photo taken by Roger Burkhalter at the Sam Noble Oklahoma Museum of Natural History at 2X magnification.

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Executive Summary

Chickasaw National Recreation Area (CHIC), located in south-central Oklahoma east of the Arbuckle Mountains, encompasses 4,001.87 ha (9,888.83 acres) of land. CHIC is best known for its wildlife, water recreation and historic Platt District. Visitors are less aware of the paleontological resources that occur in the park. During the summer of 2016, a comprehensive field inventory of paleontological resources within CHIC was conducted. The National Park Service hired two paleontology interns through the Geoscientists-in-the-Parks Program to conduct the inventory. The inventory process involved primary literature research, an extensive field survey of fossiliferous units, and inventories of collections and repositories. The field survey yielded eight new fossiliferous localities, with varying quantities of invertebrate fossils, and eight previously unidentified taxa within CHIC. This is the first report to document that the Deese Group and Sycamore Limestone are fossiliferous within the recreation area. Fossils are still present at all previously known localities (e.g. M10), except for those localities now submerged under the Lake of the Arbuckles (e.g. Girty's USGS 3981). All fossiliferous and potentially fossiliferous units, especially those around the Lake of the Arbuckles, should be regularly monitored by park staff because heavy rainstorms and erosion could expose undocumented paleontological resources over time. Collections were made of the representative fauna found within CHIC and 73 lots were accessioned into the museum collections. Some of these specimens will be given to Interpretative staff for educational use. Paleontology-themed presentations, a wayside template, and a web bulletin on the fossils found within CHIC have been provided to the Interpretation staff. This inventory report will provide a baseline source of information critical for future research, monitoring plans, and paleontological decisions at CHIC.

Acknowledgments

Sincerest thanks to members of the NPS staff including: CHIC staff members Noel Osborn, Dan Winings, Emily Clark (Resource Management), William Wright (Superintendent), Ron Parker (Chief of Interpretation), and Aaron Shandor (Chief of Law Enforcement). We would also like to thank all of the current and former staff who we interviewed. They gave us valuable insight into the awareness of paleontological resources in the recreation area. We would also like to thank Nancy Binderim for making us aware of an undocumented fossil locality. Camp Hosts Barbara and Dan Stanley lent their kayaks to survey on the lake and we are very grateful for their kindness.

Invertebrate Paleontology Curator Dr. Stephen Westrop and Invertebrate Paleontology Collections Manager Roger Burkhalter from the Sam Noble Oklahoma Museum of Science and Natural History provided support for many aspects of this report. They were instrumental during the field portion of the Chickasaw National Recreation Area PaleoBlitz and assisted with identification and information on repository specimens and are greatly appreciated.

Thanks also to Kathy Hollis at the National Museum of Natural History for providing information on CHIC specimens held in their collections. Kathy and her interns also created maps showing locations for all specimens collected within Murray County.

Many thanks to the director, Clayton Edgar, and staff at Goddard Youth Camp for being so welcoming and opening the camp to the public for the Chickasaw National Recreation Area PaleoBlitz. Clayton's knowledge led us to locate two new CHIC localities within the camp and the aid is much appreciated.

Special thanks to everyone who reviewed this report and provided essential comments and insight: Louis Zachos (University of Mississippi), Tim Connors (Natural Resource Stewardship and Science Geologic Resources Division, NPS), and Noel Osborn (Chief of Resource Management, CHIC).

This report was made possible by funding from the Geological Society of America and National Park Service through the Geoscientists-in-the-Park Program in partnership with Conservation Legacy and AmeriCorps. Many thanks.

Dedication

We dedicate this first paleontological resource inventory report for Chickasaw National Recreation Area (CHIC) to Don Weeks, Physical Resources Program Manager for the Intermountain Regional Office (IMR) of the National Park Service. We extend our gratitude to Don for his support of paleontological resource management and protection throughout the IMR and especially at CHIC. Don was instrumental in helping to support two paleontology interns at CHIC during 2016 which resulted in this report, paleontological resource field inventories, and the first NPS Paleo Blitz hosted at CHIC. Don joined the PaleoBlitz team at CHIC with paleontological resource educational outreach during the May 2016 event.

Don Weeks (NPS Photo)

Introduction

History of CHIC

Chickasaw National Recreation Area (CHIC) protects the Lake of the Arbuckles and surrounding areas in Murray County, south-central Oklahoma. The recreation area was established to protect the unique natural resources, preserve areas of cultural interest, provide outdoor recreation opportunities and to memorialize the Chickasaw Indian Nation (NPS 2008). The area was first officially recognized as Sulphur Springs Reservation on July 1, 1902, which was established to preserve a group of springs in what is now the northeastern arm of CHIC. On June 29, 1906, the boundaries were expanded and the reservation was redesignated Platt National Park. In the 1930s the Civilian Conservation Corps built pavilions, waterfalls, trails, and roads and planted over 500,000 trees and shrubs in the park. During the 1960s, construction of the Arbuckle Dam and subsequent filling of the Lake of the Arbuckles led to the creation of Arbuckle Recreation Area. This recreation area was authorized August 24, 1962 and was located to the south and west of Platt National Park. In 1967, the Goddard Youth Camp was established along the southern part of the Lake of the Arbuckles to provide immersive environmental education to youth groups. The two park units, along with additional lands, were combined and redesignated Chickasaw National Recreation Area on March 17, 1976. Currently, CHIC comprises 4,001.87 ha (9,888.83 acres), all but 1.82 ha (4.50 acres) of which are federal (Figure 1).

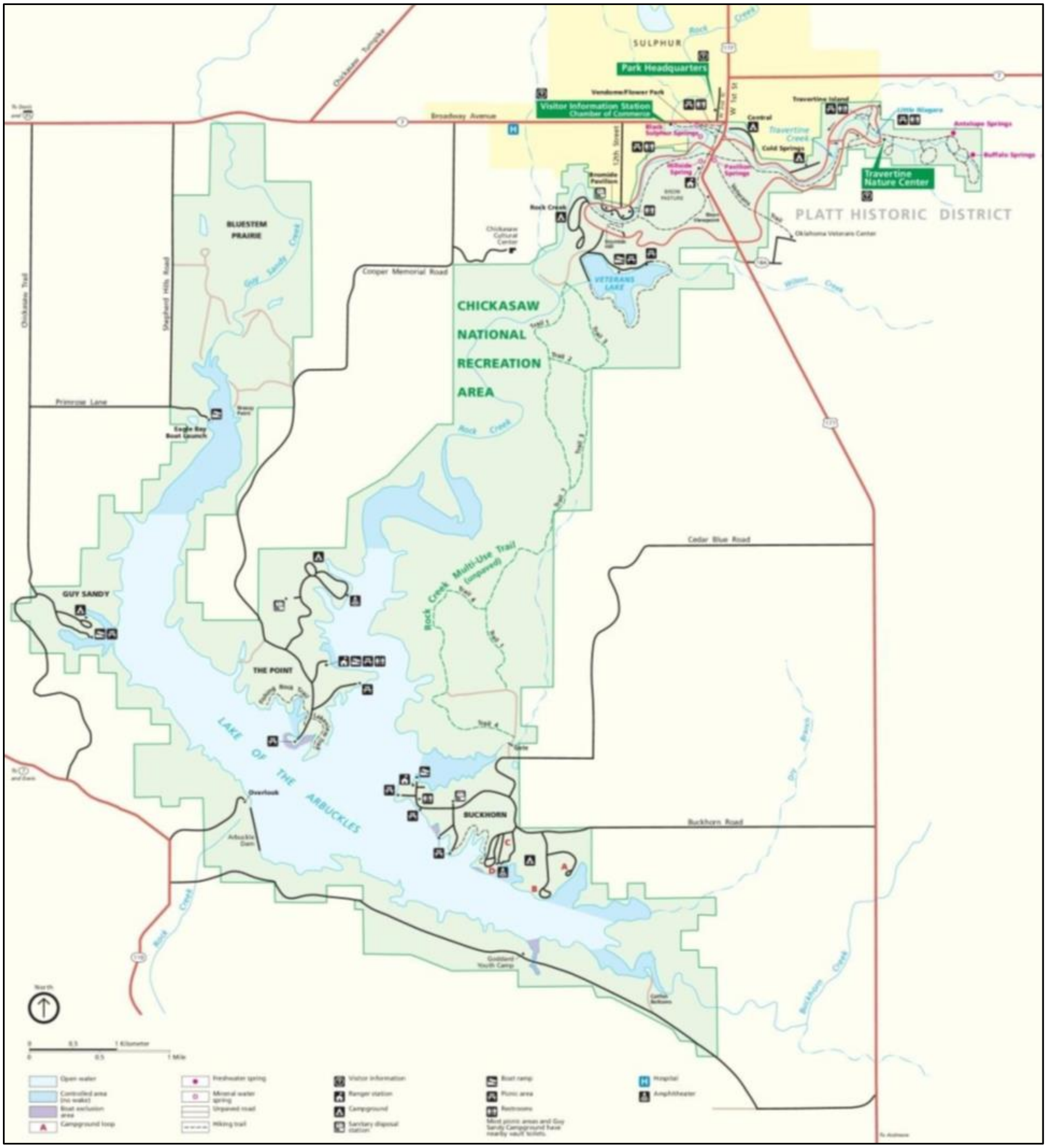

Figure 1. Area map of Chickasaw National Recreation Area (4,002 ha) located in south-central Oklahoma (NPS Graphic).

Importance of Paleontological Resources at CHIC

Chickasaw National Recreation Area and the immediate vicinity preserve an excellent geologic record of the Paleozoic Era, from approximately 500 to 300 Ma (million years ago) (Figures 2 and 3). Fossil invertebrates, vertebrates, plants, and trace fossils are documented from 11 fossiliferous stratigraphic units ranging from Middle–Late Ordovician (460–455 Ma) through the Middle Pennsylvanian (307 Ma).

Historically, numerous scientific studies have documented the fossils in CHIC, including two type specimens, one an ostracod and the other a palynomorph (see Collections section). Collections within three repositories provide researchers access for future work.

The diversity of fossils found in CHIC and the immediate vicinity provide a detailed view into the paleoecology of the area during the Paleozoic Era (Table 1). The quality of preservation is remarkable in many specimens, especially in trilobites from the Viola and Hunton groups. There are a number of localities that have provided abundant fossils in recent years, but are now temporarily under water due to rises in lake elevation. There is high potential for these units to be exposed in the near future, possibly adding a variety of new information to the already diverse fossil resources within CHIC.

Project Objectives

This inventory was initiated in order to provide park staff with baseline information on the paleontological resources found within Chickasaw National Recreation Area. This information can then be used to develop a long-term management plan that would allow compliance with NPS policy and regulations.

The project was designed to relocate previously documented localities and locate, identify and document new paleontological resource localities through field surveys. Each locality was documented with photographs and GPS data, and well-preserved specimens were collected to be stored in CHIC's collections in order to preserve the representative fauna found within the recreation area.

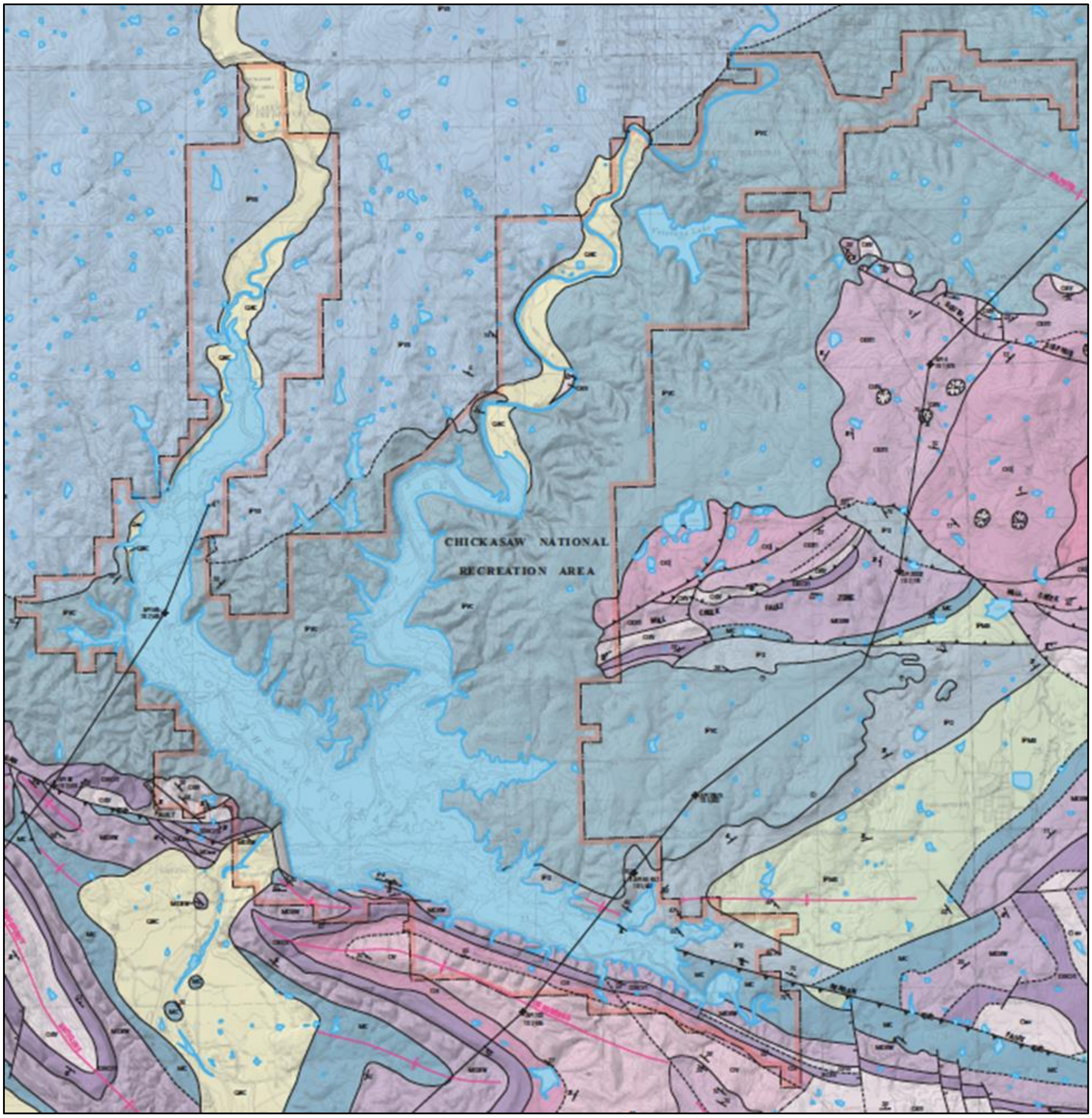

Figure 2. Geologic map of Chickasaw National Recreation Area. Park boundaries are marked with a dashed line highlighted in orange. Refer to Figure 3 for stratigraphic units (Blome et al. 2013).

Time Period	Stratigraphic Unit			Map Unit	
Quaternary	Alluvium and Colluvium			Qac	
Permian	Pontotoc Group	Stratford Formation		Ps	
Pennsylvanian	Pontotoc Group	Vanoss Formation	Vanoss shale facies	ℙvs	
Pennsylvanian	Pontotoc Group	Vanoss Formation	Vanoss conglomerate facies	ℙvc	
Pennsylvanian	Deese Group			ℙd	
Pennsylvanian	Atoka and Wapanucka Formations			ℙaw	
Pennsylvanian / Mississippian	Springer Formation			ℙMs	
Mississippian	Caney Shale			Mc	
Mississippian / Devonian	Sycamore Limestone, Welden Limestone, and Woodford Shale			MDsw	
Devonian	Hunton Group	Upper part (Haragan, Bois d'Arc)		DSOh	Dhu
Silurian	Hunton Group	Lower part (Cochrane, Clarita, Henryhouse)		DSOh	SOhl
Upper Ordovician	Sylvan Shale and Viola Group	Sylvan Shale		Osv	Os
Upper Ordovician	Sylvan Shale and Viola Group	Viola Group (Viola Springs, Welling)		Osv	Ov
Middle Ordovician	Simpson Group	Bromide, Tulip Creek, and McLish Formations		Obm	
Middle Ordovician	Simpson Group	Oil Creek and Joins Formations		Ooj	

Figure 3. Stratigraphic column with time scale and map units for CHIC. Modified from Blome et al. (2013).

Table 1. Summary of CHIC stratigraphy, fossils, and depositional environments listed from youngest to oldest. Modified from Tweet et al. (2015).

Formation	Age	Fossils Within CHIC	Depositional Environment
Quaternary sediments	Pleistocene–Holocene	None to date	Terrestrial/marine
Vanoss Formation	Late Pennsylvanian	None to date	Terrestrial/alluvial
Deese Group	Middle Pennsylvanian	Brachiopods, stalked echinoderms, bryozoans	Terrestrial/marine
Springer Formation	Late Mississippian–Early Pennsylvanian	None to date	Terrestrial/marine
Caney Shale	Middle–Late Mississippian	Brachiopods, ostracods, acanthodians	Marine
Sycamore Limestone	Early–Middle Mississippian	Stalked echinoderms, brachiopods	Marine
Woodford Shale	Late Devonian–Early Mississippian	Acritarchs, algae, ostracods, plant spores	Moderately deep marine
Hunton Group: Bois d'Arc Formation	Early Devonian	Brachiopods, crinoids, trilobites, cephalopods	Shallow marine
Hunton Group: Haragan Formation	Early Devonian	Brachiopods, bryozoans, crinoids, rugose corals, trilobites, conodonts, gastropods	Shallow marine
Hunton Group: Henryhouse Formation	Late Silurian	Brachiopods, bryozoans, corals, ostracods, trilobites, crinoids	Shallow marine
Hunton Group: Clarita Formation	Early–Middle Silurian	Brachiopods, conodonts, foraminifera, stalked echinoderms	Moderately deep marine
Hunton Group: Cochrane Formation	Early Silurian	Conodonts, invertebrate burrows	Deep marine
Sylvan Shale	Late Ordovician	None to date	Deep marine
Viola Group	Late Ordovician	Brachiopods, bryozoans, burrows, echinoderms, trilobites, ostracods	Deep marine
Simpson Group: Bromide Formation	Middle Ordovician	Potential brachiopods, ostracods	Reworked coastal sediments, then shallow marine
Simpson Group: Tulip Creek Formation	Middle Ordovician	None to date	Reworked coastal sediments, then shallow marine
Simpson Group: McLish Formation	Middle Ordovician	None to date	Shallow marine
Simpson Group: Oil Creek Formation	Middle Ordovician	None to date	Shallow marine
Simpson Group: Joins Formation	Middle Ordovician	None to date	Shallow marine

Geology

Geologic History of the Arbuckle Mountains

The Arbuckle Mountains is the common name of an area of uplift in south-central Oklahoma west of CHIC. It is mostly composed of deformed and faulted Paleozoic carbonate rocks and sandstones. The basement rock of the area is composed of Proterozoic granites rhyolites and gneisses. Northwest-trending dikes caused crust to weaken and rupture in the Early to Middle Cambrian, creating a rift. This caused major normal faults to form along its margins and igneous material intruded and extruded. The cooling of the igneous rocks caused subsidence, forming a sedimentary basin, known as the Southern Oklahoma Aulacogen (Christenson et al. 2011). The aulacogen is a failed rift associated with the breakup of Rodinia and formation of the Iapetus Ocean (Hanson et al. 2013).

Continuous subsidence and deposition occurred during the Late Cambrian through Middle Mississippian. Thinner sequences of sedimentary rock were deposited in shallow marine waters along the continental margin and thicker sequences were deposited in the subsiding basin. The collision of North America with Gondwana in the Pennsylvanian caused the deposition-subsidence cycles to end and initiated uplift and deformation, resulting in intense folding and high-angle thrust faulting. High rates of erosion followed, filling the Anadarko basin with thousands of feet of detrital sediments, and uplift and tilting in the Late Cretaceous and Early Paleogene resulted in southeast-flowing river systems, furthering the erosion of the Arbuckle Mountains (Christenson et al. 2011). These events resulted in excellent exposure of the Paleozoic Era rocks in the Arbuckle Mountains, including CHIC (Figure 3).

Rock Formations Exposed in CHIC

Simpson Group

Rocks from the Simpson Group, deposited during the Middle Ordovician (Whiterockian–Chazyan), are the oldest exposed within CHIC (Blome et al. 2013). The Simpson Group comprises five formations, in ascending order the Joins, Oil Creek, McLish, Tulip Creek, and Bromide formations. Each formation above the Joins Formation represents a marine transgression-regression cycle (Bauer 2010), and deposition of each unit started with a layer of sandstone (McPherson et al. 1988).

Joins & Oil Creek formations

The oldest formation of the Simpson Group is the Joins Formation. This formation can be as thick as 90 m (300 ft) and comprises a thin basal conglomerate with overlying thin-bedded limestone and shale. This formation was deposited in a sublittoral outer shelf setting (Shaw and Fortey 1977). The overlying Oil Creek Formation is conformable with the Joins Formation and is composed of a quartz-rich sandstone overlain by limestone and shale (Ham 1969) deposited in a shallow-marine environment (Bauer 2010). On average, this formation is 230 m (750 ft) thick. Within CHIC, the two formations are mapped together as a small outcrop on the eastern boundary of the park in the central part of Section 21, T. 1 S, R. 3 E (Blome et al. 2013). Fossils have not been reported from either formation within CHIC.

McLish, Tulip Creek & Bromide formations

The McLish Formation conformably overlies the Oil Creek Formation in the western Arbuckle Mountains but is unconformable in the east (Ham 1969). In the CHIC area, the McLish Formation is 140 to 150 m (460–490 ft) thick and is composed of a basal sandstone overlain by interbedded limestone and shale (Blome et al. 2013). The McLish Formation is a shallow-marine unit that is similar to the underlying Oil Creek Formation, although there was more influence from waves and currents (Shaw 1974). The Tulip Creek Formation lies above the McLish. In the CHIC area, the Tulip Creek Formation is composed of a basal sandstone with shale predominating in the upper part (Ham 1969). The Tulip Creek Formation was deposited at shallow subtidal depths with the basal sandstone originating from reworked coastal sediments, as is the case with all mature sandstones of the Simpson Group. Conformably overlying the Tulip Creek is the Bromide Formation, the uppermost unit of the Simpson Group. The Bromide Formation is very widespread and occurs in almost every outcrop of the Simpson Group (Ham 1969). In the CHIC area, it is composed of a basal brown to white sandstone overlain by an interbedded buff-colored limestone and grayish-green shale (Blome et al. 2013). The formation's thickness is between 96 and 197 m (315–647 ft). In the CHIC area, the Bromide Formation is mapped undifferentiated from the McLish and Tulip Creek formations (together they are the upper Simpson Group) in the central part of Section 21, T. 1 S, R. 3 E, next to the undivided Joins and Oil Creek formations (Blome et al. 2013).

The McLish and Tulip Creek formations are not reported to be fossiliferous within CHIC. The Bromide Formation is very fossiliferous, but there have not been any definite reports of fossils from within CHIC. A report of bryozoans, brachiopods, bivalves, ostracods, trilobites, echinoderms, and graptolites (Koch and Santucci 2003) appears to be a reference to the fauna found within the Bromide Formation as a whole, not specifically from within CHIC (Tweet et al. 2015). Blome et al. (2013) noted that within the mapping area (including CHIC), the limestone is commonly fossiliferous, preserving ostracods and brachiopods, however no fossils were found during the 2016 survey.

Viola Group

The Viola Group is a 150 to 210 m (500–700 ft) thick unit (Taff 1904) consisting of the Viola Springs Formation overlain by the Welling Formation. The Viola Springs Formation is composed of white to blue-gray chert-rich limestone, interbedded with thin layers of green-gray shale (Blome et al. 2013). It grades into the Welling Formation, which is a thinner unit composed of coarser gray limestone (Blome et al. 2013). The Welling Formation is interpreted as having a gradational contact with the Sylvan Shale (Amsden and Sweet 1983), but a paleokarst surface suggests that there was a period of non-deposition (Sykes et al. 1997). The Viola Group and the Sylvan Shale are mapped undifferentiated in CHIC in a small area near the mid-north boundary of Section 16, T. 1 S, R. 3 E, northwest of the Arbuckle Dam; and in the south-central part of Section 21, T. 1 S, R. 3 E. The Viola Group is mapped by itself along the southern boundary of CHIC (Blome et al. 2013).

The Viola Group is early Late Ordovician in age (late Mohawkian to early Cincinnatian) (Derby et al. 1991). It was deposited in deeper waters than the Simpson Group, as suggested by fewer fossils indicating a less oxygenated bottom (Finney 1988). There have been reports of several brachiopod species (Alberstadt 1967, 1973) and an abundance of trilobites and echinoderms (Glaser 1965; Alberstadt 1967, 1973) in the Welling Formation within CHIC. Fossils of these taxa as well as cephalopods are still found in the recreation area. Thin sections have also shown bryozoans, ostracods, and possible evidence of burrowing (Glaser 1965). Graptolites have also been found in the Welling Formation outside of CHIC (Decker 1933). The Viola Springs Formation preserves abundant, well-preserved trilobites within CHIC.

Sylvan Shale

The Sylvan Shale is a shale layer bounded by the carbonate units of the Viola Group and the Hunton Group. The Sylvan Shale is green, gray, and tan lime- and dolomite-rich shale. Exposures are not common because of the unit's vulnerability to weathering. The thickness ranges from 15 to 90 m (50–300 ft). The Sylvan Shale is sometimes mapped undifferentiated from the underlying Viola Group, and is mapped alone along the southern boundary of CHIC (Blome et al. 2013).

The Sylvan Shale is middle Late Ordovician in age (Richmondian). The unit was deposited during a marine transgression (Eriksson and Leslie 2003) under low-energy conditions and was likely deposited in a deeper water environment compared to the Viola and Simpson groups (Jenkins 1970). There is a lack of fossils which suggests an anoxic environment (Playford and Wicander 2006). Most fossils have been found in the lower part of the unit, and the upper part may be completely deficient of macrofossils (Jenkins 1970). No fossils have been found in the Sylvan Shale within CHIC boundaries.

Hunton Group

The Hunton Group comprises thin beds of white to light-blue crystalline limestone, thin tan limestone, and marls (Taff 1904). The Hunton was deposited in a low-energy, shallow marine environment on a gently sloping ramp (Al-Shaieb et al. 2001). Sea level fluctuations caused periods of non-deposition and some units experienced complete erosion before the succeeding unit was deposited (Amsden 1960). Five formations are present in CHIC, in ascending order the Cochrane, Clarita, Henryhouse, Haragan, and Bois d'Arc formations. The formations of the Hunton Group are mapped undifferentiated in CHIC along the southern boundary, northwest of the Arbuckle Dam, and in the central portion of Section 21, T. 1 S, R. 3 E. Near the southeastern boundary they are divided into the Lower and Upper Hunton Groups (Blome et al. 2013). The Lower Hunton Group consists of the Cochrane, Clarita, and Henryhouse formations, and the Upper Hunton Group consists of Haragan and Bois d'Arc formations.

Cochrane Formation

The Cochrane Formation is composed of highly indurated, white to bluish or greenish-gray limestone with a thickness of 4 to 5 m (12–15 ft) (Blome et al. 2013). This formation was deposited in the late Early Silurian (late Llandovery) (Al-Shaieb et al. 2001). Invertebrate burrows (Stanley 2001) and conodont fossils have been reported in the Cochrane Formation at the M10 section (see Localities section for a full description of the M10 site) SW¼, SE¼ of Section 33, T. 1 S, R. 2 E, within CHIC (Amsden 1960).

Clarita Formation

In the CHIC area, the Clarita Formation is mostly composed of fine-grained limestone. It is composed of two members, the Prices Falls Member and overlying Fitzhugh Member. The Lower Silurian Prices Falls Member (Llandovery) is composed of shales and marls, and the Middle Silurian Fitzhugh Member (Wenlock) is composed of limestone. The formation is up to 14 m (45 ft) thick, most of which is made up of the Fitzhugh Member. The Prices Falls Member never exceeds 0.5 m (1.6 ft) thick (Blome et al. 2003). The Clarita Formation was deposited in moderately deep water during the transition from Early to Middle Silurian (Amsden et al. 1980).

The Clarita Formation has been reported as fossiliferous within CHIC. Stalked echinoderms, brachiopods, foraminifera, and conodonts have been documented (Amsden 1960, 1968). The Fitzhugh Member is highly fossiliferous northeast of CHIC, but the facies of the formation present within CHIC boundaries is more mud-rich and has fewer fossils (Amsden et al. 1980). During the 2016 survey, no outcrops of the Clarita Formation were observed.

Henryhouse Formation

The Henryhouse Formation is composed of variegated limestone with layers of yellow shale in the lower part. It is typically around 27 m (90 ft) thick, but can be up to 65 m (220 ft) thick (Blome et al. 2013). It was deposited during the Late Silurian (Ludlow–Pridoli) (Barrick and Klapper 1992) in a low-energy, shallow marine setting (Al-Shaieb et al. 2001). The contact between the Henryhouse Formation and the Haragan Formation is disconformable (Lehman 1945; Amsden 1962; Barrick and Klapper 1992). The two formations have similar lithologies, but are differentiated by their faunal assemblages (Barrick and Klapper 1990, 1992).

Within CHIC, the Henryhouse Formation is fossiliferous. At the M10 locality, the lower part of the Henryhouse Formation has been described as having no fossils, the middle part having corals, bryozoans, brachiopods, and trilobites, and the upper part having bryozoans, brachiopods, and trilobites (Amsden 1960). Rugose corals (Sutherland 1965) and ostracods (Lundin 1968) have also been found here. Crinoids were reported at the M10 locality (Stanley 2001). All of these taxa, except ostracods and crinoids, were documented during the survey, although they were attributed to a combined Henryhouse/Haragan designation due to difficulty in differentiating the two formations.

Haragan Formation

The Haragan Formation is one of the most fossiliferous units within CHIC boundaries. It is composed of alternating bluish to white shale, limestone, and yellow- to tan-weathering mudstone. On average it is 30 m (100 ft) thick, but can get as thick as 51 m (166 ft) (Blome et al. 2013). It was deposited in a warm, continental sea with a somewhat turbid, muddy bottom (Amsden 1958a) during the early Early Devonian (Lochkovian) (Barrick and Klapper 1992). The abundance of encrusting fauna, like corals and bryozoans, on vacant shells indicates that sedimentation rates were slow (Cuffey et al. 1995). Its upper contact grades into the Bois d'Arc Formation (Stanley 2001), and the two units can sometimes be undifferentiable (Lundin 1967; Campbell 1977).

The Haragan Formation is fossiliferous within CHIC. The M10 site has abundant rugose corals, bryozoans, brachiopods, trilobites, and crinoids (Amsden 1958a; Campbell 1977). Other sites (CHIC

PAL 001 and CHIC PAL 002) were found to preserve these same taxa during the 2016 survey. Barrick and Klapper (1992) discussed conodonts and Amsden (1960) reported gastropods from M10. Stanley (2001) reported bivalves and burrows at Haragan localities outside of CHIC. Common ostracods found in the Henryhouse Formation were reported to have been reworked into the lower part of the Haragan Formation (Lundin 1968).

Bois d'Arc Formation

The Bois d'Arc Formation is composed of limestone with some chert and shale. It averages 20 m (60 ft) thick, and can get up to 27 m (90 ft) thick (Blome et al. 2003). It is divided into two members: the lower Cravatt Member and the upper Fittstown Member. The Cravatt Member is rich in chert and the Fittstown Member is composed of calcarenite. The two members have a gradational contact (Amsden 1958b). Deposition occurred towards the end of the early Early Devonian (Lochkovian). The upper contact with the Woodford Shale is disconformable (Lehman 1945). The Bois d'Arc Formation looks similar to the Haragan Formation, but the two can be differentiated by the higher chert content in the Bois d'Arc (Lundin 1967).

The Cravatt Member was deposited in calmer, deeper water than the Fittstown Member (Stanley 2013). It is thought that the environmental setting for the Cravatt Member was similar to that of the Haragan, while the Fittstown Member is interpreted as being formed from invertebrate remnants buried in situ (Amsden 1958b).

Within CHIC boundaries, the Bois d'Arc Formation is fossiliferous. The fossil assemblages are similar to those of the Haragan Formation (Reeds 1911; Amsden 1958b). At the M10 locality, there have been reports of brachiopod and crinoid fragments in the Cravatt Member and brachiopods, crinoids, and trilobite fragments in the Fittstown Member (Stanley 2001). Large crinoid stems were also found at locality CHIC PAL 002 during the 2016 survey.

Woodford Shale

The Woodford Shale lies disconformably over the Bois d'Arc Formation of the Hunton Group. In CHIC, it is composed of dark shale and bedded chert, with phosphatic concretions in the lower part (Blome et al. 2013). The Woodford Shale is up to 1,830 m (6,000 ft) thick, but within CHIC it is between 20 and 210 m (200 and 700 ft) thick (Ham 1969; Blome et al. 2013). Within the boundaries of CHIC, the Woodford Shale is mapped undivided from the Welden Limestone and Sycamore Limestone. The three units are mapped in the southern part of Section 21, T. 1 S, T. 3 E, to the northwest and southeast of the Arbuckle Dam (Blome et al. 2013).

The Woodford Shale was deposited 380–355 Ma, from the late Devonian (Frasnian) into the early Mississippian (Kinderhookian) (Becker and Mapes 2010). It was deposited in a deeper marine environment than the underlying Hunton Group, during a marine highstand (Brown and Grayson 1985). There was little sediment input, and phosphate beds and nodules near the top of the unit records the effects of marine upwelling (Over and Barrick 1990).

Within CHIC, the Woodford Shale is fossiliferous at a locality near Buckhorn Creek. A new genus and species of palynomorph, *Quisquilites buckhornensis,* was described from the lower part of the formation (Wilson and Urban 1963). Plant spores, the prasinophyte alga *Tasmanites* and acritarchs have been reported from the same locality (Wilson and Urban 1963).

Sycamore Limestone

Within CHIC, the Sycamore Limestone is composed of fine-grained, silty and cherty limestone with thin layers of dark-gray shale and lime-rich siltstone overlain by dark-gray shale and tan marlstone (Ham 1969; Blome et al. 2013). This unit is mapped undivided from the Woodford Shale and Welden Limestone in the southern part of Section 21, T. 1 S, T. 3 E (Blome et al. 2013). The stratigraphic nomenclature is complicated for the Woodford Shale, Welden Formation, Sycamore Limestone and Caney Shale in the Arbuckle Mountains (Braun 1959; Champlin 1959; Chenoweth et al. 1959). During the 2016 survey these units were able to be differentiated. At one fossiliferous locality, a contact is visible between the Woodford and Sycamore.

The complicated nomenclature and scarcity of fossils result in the dating of the Sycamore Limestone varying between publications. Deposition most likely began in the Early Mississippian (Kinderhookian or Osagean) and ended during the middle Mississippian (Meramecian), approximately 335 Ma (Ormiston and Lane 1976; Pessagno et al. 1983; Donovan 2001). Deposition occurred during a marine transgression (Braun 1959), and there are several facies, from shallow-marine shale to deep-water limestone and shale (Cole 1988). On the south side of the mountains, the lower part of the Sycamore Limestone has many carbonate beds, and these are assigned to the Welden Limestone (Donovan 2001). The contact with the overlying Caney Shale is gradational (Chenoweth et al. 1959) to disconformable (Donovan 2001).

The Sycamore Limestone is fossiliferous at one locality within CHIC. Brachiopods and echinoderm stalks and columnals were documented during the 2016 survey (Figure 4), the first documented fossils from this formation in the recreation area. Few fossils have been reported in general, and they are most often found within the limestone beds. (Braun 1959).

Figure 4. Stalked echinoderm columnals preserved in the Sycamore Limestone at locality CHIC PAL 003 (NPS Photo).

Caney Shale

In CHIC, the Caney Shale is composed of dark-gray to black shale with concretions and is up to 120 m (400 ft) thick. Within the boundaries of CHIC, the Caney Shale is mapped in the southeast corner, south of the Reagan Fault (Blome et al. 2013). As with the Sycamore Limestone, this unit has a complicated nomenclatural history.

North of the Arbuckles, the Caney Shale can be divided into as many as three members, in ascending order: the Ahloso, Delaware Creek, and Sand Branch members. The contacts between these members are arbitrary, but the presence of phosphatic concretions distinguishes the Sand Branch Member from the other two (Elias and Branson 1959). The Ahloso Member is believed to be equivalent to the Sycamore Limestone, which is predominant in the southern Arbuckles (Chaplin 1959; Chenoweth et al. 1959).

The Caney Shale was deposited 335–323 Ma, during the Middle and Late Mississippian (Meramecian and Chesterian) (Elias and Branson 1959) in a basin that was part of the aulacogen (Donovan 2001). The upper contact with the Springer Formation is described as either conformable (Boardman et al. 2009) or as disconformable (Wilson 1966).

The Caney Shale is fossiliferous within CHIC. However, the most productive locality is presently submerged under the lake of the Arbuckles (see USGS 3981 in Localities section). Brachiopods and ostracods were reported at USGS 3981 and a new species of ostracod, *Entomis unicornis*, was named (Girty 1909). Fossils have been found at two other USGS localities, USGS 3914 and USGS 3915, but

USGS 3915 may be a Deese Group Locality (Tweet et al. 2015). Zidek (1972, 1975) briefly discussed an indeterminate acanthodian from a now-submerged locality.

Deese Group

In the CHIC area, the Deese Group is composed of beds of sandstone, conglomerate, limestone, and gray and red shale (Blome et al. 2013). It can be over 2,740 m (9,000 ft) thick. Within the recreation area boundaries, it is mapped in a small area east of the Arbuckle Dam and in the southeastern corner to the north of the Reagan Fault (Blome et al. 2013).

The Deese Group was deposited in the late Middle Pennsylvanian (Desmoinesian), about 310 Ma, in a variety of depositional settings (Blome et al. 2013). Deposition occurred in rivers, deltas, lagoons, estuaries and shallow equatorial water (Brand 1987). Conglomerate beds correspond to pulses of tectonic activity (Billingsley et al. 1996). The contact with the overlying Vanoss Formation is a disconformity (Blome et al. 2013).

The Deese Group is not abundantly fossiliferous within CHIC. A few brachiopods and echinoderm stem fragments and a single bryozoan were found within the matrix of the conglomerate facies. These fossils were documented during the 2016 survey (Figure 5) and it is the first time fossils have been reported from this formation from within CHIC. Just outside of CHIC, the Buckhorn Asphalt Quarry has produced abundant fossils (see Localities near Chickasaw National Recreation Area section).

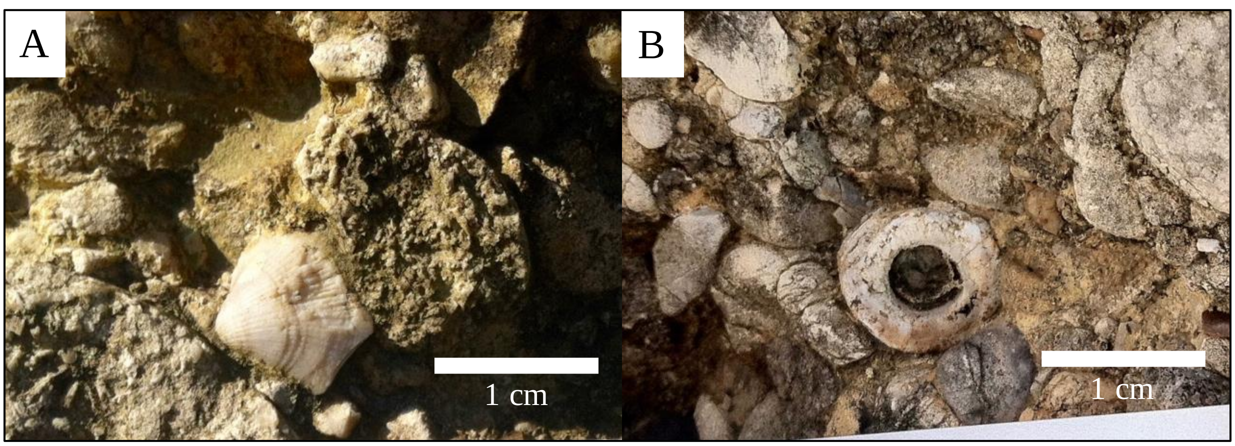

Figure 5. Fossils preserved in the matrix of the Deese Group conglomerate facies. A) A brachiopod. B) An echinoderm stalk (NPS Photos).

Vanoss Formation

The Vanoss Formation has the largest exposed surface extent in CHIC (Blome et al. 2013). The Vanoss is flat-lying over heavily folded formations, indicating that it was deposited after most of the major tectonic activity in the area (Lang 1966; Donovan and Heinlen 1988). The Vanoss Formation consists of a lower limestone conglomerate facies and an upper shale facies. Clasts in the limestone conglomerate facies include limestone and dolomite clasts eroded from the Simpson and Arbuckle Groups, along with some granitic clasts from basement rocks (Scheirer and Scheirer 2006). The limestone conglomerate facies has a maximum thickness of 150 m (500 ft), but averages 30 m (100 ft) and has a gradational contact with the shale facies. The shale facies is composed of shale with some silt, sandstone, and local beds of conglomerate and is between 9 and 24 m (30–80 ft) thick (Blome et al. 2013).

The Vanoss Formation was deposited in the Late Pennsylvanian (Virgilian) as terrestrial, alluvium deposits from the north side of the Arbuckle Mountains, which at the time were newly formed (Donovan and Heinlen 1988). Few fossils have been reported in the Vanoss Formation, and none have been found within CHIC (Tweet et al. 2015).

Quaternary sediments

The Quaternary sediments in CHIC are alluvium and colluvium consisting of silt, clay, gravel, and sand. Occurrences are typically 1 to 15 m (3–50 ft) thick. The Quaternary sediments are mostly mapped in the floodplains of streams and below the Arbuckle Dam (Blome et al. 2013). In the northeastern part of CHIC, along the creek floodplains, the sediment is dominantly sand with some areas dominated by mud.

Paleontological Resource Inventory

During the fossil survey the Henryhouse and Haragan formations were not differentiable at localities M10 and CHIC PAL 001. Therefore, a combined designation is used (Henryhouse/Haragan formations [Upper Silurian–Lower Devonian]) and all specimens listed under this category were collected during the 2016 survey even if not specifically stated. For a list of all specimens collected during the 2016 survey see Appendix A.

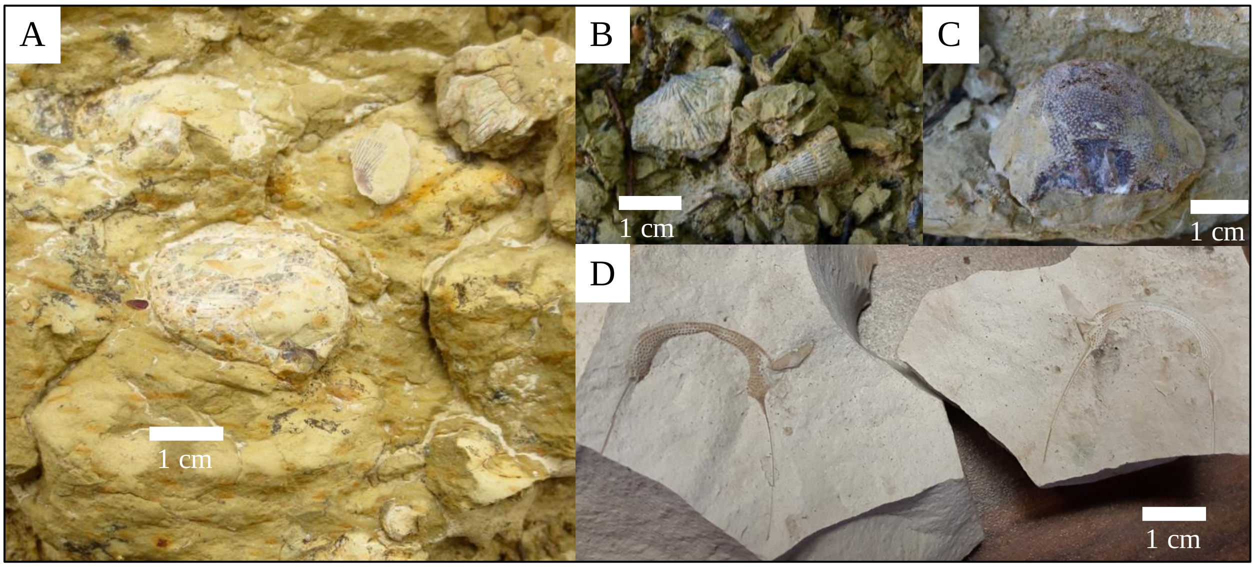

Figure 6. Some of the common fossils found within CHIC. A) A coral and brachiopods and B) a brachiopod and rugose coral from the Henryhouse/Haragan formation at CHIC PAL 001. C) *Stromatotrypa* sp., a bryozoan from the Henryhouse/Haragan formation at CHIC PAL 009 (M10). D) Part and counterpart of two *Cryptolithoides ulrichi* from the Viola Springs Formation at CHIC PAL 015 ("Veterans Lake" echinoderm locality) (NPS Photos).

Fossil Protists

Kingdom Protista

<u>Order Foraminiferida</u>

Caney Shale or Deese Group (Mississippian or Pennsylvanian) *Fusulinia* sp. from USGS locality 3915 (Tweet et al. 2015).

Clarita Formation (Lower–Middle Silurian) Arenaceous foraminifera have been found at the M10 locality in the southern part of CHIC (Amsden 1960).

Fossil Plants

Kingdom Plantae

Woodford Shale (Upper Devonian- Lower Mississippian) *Tasmanites*, and the type specimen of the palynomorph *Quisquilites buckhornensis* (SNOMNH OPC 7026-19036) were found at locality CHIC PAL 016.

Fossil Invertebrates

Kingdom Animalia

Phylum Cnidaria

Henryhouse Formation (Upper Silurian) The rugose corals *cf. Pseudocryptophyllum* sp. A and *Syringaxon adaense* were found in bed G of the M10 locality (Sutherland 1965).

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) Rugose corals were collected from localities M10 and CHIC PAL 001 during the 2016 survey.

Haragan Formation (Lower Devonian) Rugose corals were found at the M10 locality, but were not identified further (Amsden 1960). A rugose coral was collected at the CHIC PAL 002 locality during the 2016 survey.

Phylum Bryozoa

Viola Group (Upper Ordovician) Glaser (1965) reported bryozoans in Section G, subunit 3C located along the southern boundary of CHIC.

Henryhouse Formation (Upper Silurian) Bryozoans were found in the middle and upper parts of this formation at the M10 locality (Amsden 1960).

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) *Cyphotrypa corrugata and Stromatotrypa* sp, were collected from the M10 locality. An unidentified encrusting bryozoa and several specimens of *Cyphotrypa corrugata* were collected from CHIC PAL 001.

Haragan Formation (Lower Devonian) Free-living and epizoic forms have been found at the M10 locality (Cuffey et al. 1995a). The taxa include *Ceramopora imbricata, Cyclotrypa mutabilis, Cyphotrypa corrugata, Fenestella idalia, Fenestella*? *cf. lilia, Fistuliporella mynardi, Fistuliporella quinquedentata, Leioclema subramosum* (alternative spelling *Lioclema*). Both branching and fenestrate forms were collected from the CHIC PAL 002 locality during the 2016 survey.

Deese Group (Middle Pennsylvanian) One unidentified bryozoa was found in the matrix of the conglomerate facies at locality CHIC PAL 004.

Phylum Brachiopoda

Viola Group (Upper Ordovician) *Austinella* sp., *Austinella multicostella, Lepidocyclus cooperi, Lepidocyclus capax, Paucicrura* sp., *Paucicrura oklahomensis* (genus synonymous with both *Cristiferina* Cooper 1956 and *Sigopallus*), *Eochonetes magna*, and *Strophomena planumbona* were found in the Welling Formation at the End of Section G locality (Alberstadt 1967, 1973). *Austinella* sp., *Lepidocyclus cooperi*, and *Lepidocyclus oblongus* were collected at the “Veterans Lake” echinoderm locality during the 2016 survey. At locality CHIC PAL 008, several poorly preserved specimens were found but not collected.

Clarita Formation (Lower–Middle Silurian) Brachiopods were reported at the M10 locality but not identified or collected from the Clarita Formation (Amsden 1960).

Henryhouse Formation (Upper Silurian) *Atrypa tennesseensis, Coelospira safordi, Spirifer* (*Delthyris*) sp., *Leptaena* sp., *Lissostrophia* (*L.*) *cooperi, Lissatrypoidea* sp., *Lissatrypoidea concentrica, Merista oklahomensis, Pseudodicoclosia oklahomensis, Resserella brownsportensis, Rhipidomelloides henryhousensis* (synonymized with *Dalejina*), *Sieberella roemeri, Strixella acutisulcata, Stropheodonta* (*B.*) *attenuata* (synonymous with *Strophomena*), *Strophonella loeblichi*, and *Strophonella prolongata* were found and collected in the middle and upper parts of the Henryhouse Formation at locality M10 (Amsden 1960).

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) *Kozlowskiella* (*Megakozlowskiella*) *velata, Levenea* sp., *Levenea subcarinata pumilis, Lissostrophia*? *cooperi, Meristella atoka, cf. Orbiculoidea* (Figure 7), *Orthostrophia strophomenoides, Ptychopleurella* ?*rugiplicata, Rhipidomelloides oblata* (synonymized with *Dalejina*), and *Rhynchospirina maxwelli*, were collected from M10. *Atrypa oklahomensis, Dicoelosia varica, Kozlowskiella* (*Megakozlowskiella*) *velata, Leptaena acuticuspidata, Levenea subcarinata pumilis, Meristella atoka, Obturamentella*? *wadei, Orthostrophia strophomenoides, Rhipidomelloides oblata, Schuchertella attenuata*, and *Sphaerirhynchia? lindenensis* were collected from locality CHIC PAL 001.

Figure 7. One of two specimens of *cf. Orbiculoidea* collected during the 2016 field survey (NPS photo).

Haragan Formation (Lower Devonian) *Atrypina hami, Camaroteochia? haraganensis, Coelospira virginia, Cyrtina dalmani nana, Dicoelsia varica, Howellella cycloptera, Isorthis pygmaea, Kozlowskiella (Megakozlowskiella) velata* (replaced by *Kozlowskiellina* Boucot, 1958), *Leptaena acuticuspidata, Leptaenisca concava, Levenea subcarinata pumilis, Meristella atoka, Nucleospira ventricosa, Obturamentella wadei, Orthostrophia strophomenoides parva, Renesselaerina haragana, Rhipidomelloides oblata* (synonymized with *Dalejina*), *Rhynchospirina maxwelli,* *Schuchertella haraganensis* (alternative names are *Orthothetes* and *Streptorhynchus*), *Sphaerirhynchia glomerosa*, *Sphaerirhynchia lindenensis*, *Stropheodonta* (*Brachyprion*) *gibbera*, *Stropheodonta* (*Brachyprion*) *arata*, and *Strophonella* (*Strophonella*) *bransoni* were found and collected at the M10 locality (Amsden 1958a, 1960). *Levenea subcarinata pumilis* and *Sphaerirhynchia lindenensis* were collected from CHIC PAL 002 during the 2016 survey.

Bois d'Arc Formation (Lower Devonian) *Howellella cycloptera*, *Leptaena cf. Leptaena rhomoidalis*, *Meristella atoka*, *Rhipidomelloides oblata* (synonymous with *Dalejina*), *Sphaerirhynchia lindenensis*, and *Strophonella* (*Strophonella*) *bransoni* were collected from the M10 locality (Amsden 1958b, 1960). Several brachiopods were found but not collected at locality CHIC 007 during the 2016 survey.

Caney Shale (Middle–Late Mississippian) *Productella hirsutiformis* was found in the Caney Shale at Girty's USGS 3981 locality (Girty 1909). *Productus* was collected from USGS 3915 (Tweet et al. 2015), although this is potentially a Deese Group locality.

Deese Group (Middle Pennsylvanian) *Leptaena* sp. and *Orthostrophella*? *clairensis* were collected and other brachiopods were found at locality CHIC PAL 004. Several poorly preserved specimens were found at CHIC PAL 005.

<u>Phylum Arthropoda</u>

Subphylum Crustacea

<u>*Class Ostracoda*</u>

Viola Group (Upper Ordovician) Ostracods were reported from the upper calcarenites of Section G, subunit 3C by Glaser (1965).

Haragan Formation (Lower Devonian) *Parabolbina scotti* was found at M10 (Lundin 1968). Other ostracods at this site, typical of the Henryhouse Formation, were noted as being reworked into the lower Haragan Formation (Lundin 1968). Amsden (1960) also reported collecting ostracods from the M10 locality but did not describe the taxa.

Caney Shale (Middle–Upper Mississippian) *Cytherella aff. benniei* and the type specimen of *Sansabella unicornis* (USNM PAL 120749) Bassler and Kellett 1934 (originally *Entomis unicornis*) were collected from the Ahloso Member at locality USGS 3981 (Girty 1909).

Subphylum Trilobitomorpha

<u>*Class Trilobita*</u>

Viola Group (Upper Ordovician) *Cryptolithoides ulrichi* are abundant in the Viola Springs Formation at the "Veterans Lake" echinoderm locality. Trilobites were reported as being abundant in the Welling Formation at the End of Section G locality, however none were collected and taxonomic designations were not listed (Glaser 1965; Alberstadt 1967). Unidentifiable pygidium and cephalon segments were found in the Welling Formation at the "Veterans Lake" echinoderm locality during the 2016 survey.

Henryhouse Formation (Upper Silurian) *Ananaspis guttulus*, *Calymene clavicular*, *Dalmanites rutellum*, *Proteus foculus* (Campbell 1967), *Eophacops?* sp. and fragments of dalmanitid trilobites (Amsden 1960) were collected from the M10 site.

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) *Huntonia* sp., and *Kainops raymondi* were collected from the M10 site. At CHIC PAL 001 *Reedops deckeri* and an unidentified thorax were collected.

Haragan Formation (Lower Devonian) *Kainops raymondi* and *Reedops deckeri* (alternative name *Reedops lochovella* Adamek 2013) were collected from the Haragan Formation at the M10 site (Campbell 1977). *Kainops raymondi* and an unidentifiable pygidium were found at locality CHIC PAL 002.

Bois d'Arc Formation (Lower Devonian) *Paciphacops (Paciphacops) invius* was found at the M10 site (Campbell 1977).

Phylum Mollusca

Class Cephalopoda

Viola Group (Upper Ordovician) It was reported that "some" cephalopods are present in subunit 3C (Welling Formation) of the End of Section G locality (Glaser 1965).

Subclass Nautiloidea

Viola Group (Upper Ordovician) The 2016 survey yielded two partial specimens of *Orthoceras* (composed of three and four segments) at the End of Section G locality.

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) An *Orthoceras* was collected at the M10 locality during the 2016 survey.

Class Gastropoda

Haragan Formation (Lower Devonian) Gastropods were found but were not described or collected (Amsden 1960).

Phylum Echinodermata

Viola Group (Upper Ordovician) Crown plates and individual columnals from crinoids have been found in the Welling Formation at the End of Section G locality (Glaser 1965; Alberstadt 1967). During the 2016 survey, a stalked echinoderm calyx was found and many highly fossiliferous rocks composed primarily of disarticulated stalked echinoderm columnals were collected in the Welling Formation at the "Veterans Lake" echinoderm locality. Several echinoderm stalk segments were also found at CHIC PAL 008.

Clarita Formation (Lower–Middle Silurian) Stalked echinoderm plates were found at locality M10 (Amsden 1960).

Henryhouse/Haragan formations (Upper Silurian–Lower Devonian) Crinoids have been reported at the M10 locality (Stanley 2001). A calyx fragment and several stalked echinoderm columnal fragments were collected (some with circular lumen, others with star-shaped lumen) from CHIC PAL 001.

Haragan Formation (Lower Devonian) The crinoid *Camarocrinus* along with individual holdfasts and columnals have been found at the M10 locality (Amsden 1960). Stalked echinoderm columnal fragments were collected from CHIC PAL 002.

Bois d'Arc Formation (Lower Devonian) The 2016 survey yielded multiple segments of echinoderm stems from the CHIC PAL 002 and CHIC PAL 007 localities.

Sycamore Limestone (Lower-Middle Mississippian) Echinoderm stalk segments were found at localities CHIC PAL 003, CHIC PAL 004, and CHIC PAL 006.

Fossil Vertebrates

Kingdom Animalia

<u>Phylum Chordata</u>

Class Acanthodii

Caney Shale (Middle–Upper Mississippian) An indeterminate species of acanthodian fish was collected from the Delaware Creek Member (Zidek 1972, 1975) at a locality now submerged under the Lake of the Arbuckles. It is housed at the American Museum of Natural History as AMNH 425.

Class Conodonta

Cochrane Formation (Lower Silurian) Conodonts were reported to have been found at the M10 locality, but no descriptions were included (Amsden 1960).

Clarita Formation (Lower–Middle Silurian) Conodonts were reported to have been found at the M10 locality, but no descriptions were included (Amsden 1960; Blome et. al 2013).

Haragan Formation (Lower Devonian) Conodonts were reported to have been found at the M10 locality, but no descriptions were included (Barrick and Clapper 1992).

Trace Fossils

Viola Formation (Upper Ordovician) Burrows were found in the northern part of the 'Veterans Lake" echinoderm locality during the 2016 survey.

Cochrane Formation (Lower Silurian) Invertebrate burrows were reported at the M10 locality (Stanley 2001).

CHIC Paleontological Resource Localities

Southern Boundary of CHIC

CHIC PAL 001

The Henryhouse and Haragan formations are exposed on a section of trail about 84 m (275 ft) long (Figure 8). Small outcrops on either side of the trail range in thickness from 0 to 1.2 m (0–4 ft) and bedding is occasionally visible below the soil profile (Figure 8). The fossils are in good condition although most are found weathered out of the rock and scattered along the trail. Brachiopods are the most common fossils found while rugose coral, bryozoans, trilobites are present but not as abundant.

Figure 8. A section of the CHIC PAL 001 locality showing the 1.2 m (4 ft) of exposure on the right with slight bedding (NPS Photo).

CHIC PAL 002

The Haragan and Bois d'Arc formations are exposed along the trail south of the fork along a section that is 28.6 m (94 ft) long. The creation of the trail exposed these two formations so they are only visible on the path, not as outcrops along the sides. The Haragan Formation extends 6.7 m (22 ft) and contains the same fossils found at CHIC PAL 001, while the Bois d'Arc extends 22 m (72 ft) and contains abundant large stalked echinoderm columnals and fewer brachiopods. The quality of fossil preservation is variable.

CHIC PAL 009 (M10)

The M10 locality has been a highly studied area. In the Cochrane Formation, Amsden (1960) reported conodonts east of a stream that flowed into Little Buckhorn Creek. In the Clarita Formation, Amsden (1958a, 1960) described foraminifera, brachiopods, stalked echinoderms, and conodonts. In the Henryhouse Formation, Sutherland (1965) described rugose corals and Campbell (1967) described trilobites. In 1968, Lundin described ostracods from the Haragan Formation, but noting their similarity to the Henryhouse ostracods, suggested they had been reworked into the Haragan sediment. Rugose corals, brachiopods, mollusks, trilobites, ostracods, and crinoid holdfasts were reported in the Haragan Formation (Amsden 1960). Brachiopods (Amsden 1958b, 1960) and trilobites (Campbell 1977) were found in the Fittstown Member of the Bois d'Arc Formation. Amsden (1960) reported unspecified fossils in the Cravatt Member. The end of section M10 is currently slumped due to flooding in May 2015. After evaluation of the site, it is likely the Haragan Formation, and there is an abundance of corals, bryozoans, brachiopods, trilobites, and stalked echinoderm columnals. The lower strata of the M10 locality were probably covered when the Goddard Youth Camp Road was constructed.

CHIC PAL 010 (End of Section G)

Section G begins outside of CHIC and ends within the recreation area (Glaser 1965; Alberstadt 1967, 1973). The Viola Group and Sylvan Shale are present within this section, but only the Viola Group in the upper part of the section (unit 3, subunit 3C) is currently exposed within CHIC. Subunit 3C, now considered the Welling Formation, has abundant trilobites and echinoderms and several species of brachiopod (Glaser 1965; Alberstadt 1967, 1973). Pieces of bryozoans, brachiopods, ostracods, trilobites, echinoderms, and possible evidence of burrowing were also reported from petrographic thin sections. During the 2016 survey, brachiopods, a trilobite and stalked echinoderm columnals were found. A lingulid brachiopod was also found near this site, but it is of unclear provenance.

Lake of the Arbuckles

CHIC PAL 003

This locality has an exposure of Woodford Shale and Sycamore Limestone. The Sycamore Limestone has many chert bands and preserves brachiopods and echinoderm stems. This is the only locality known within CHIC with fossils preserved in the Sycamore.

CHIC PAL 004

This locality is mapped as Deese but the eastern corner may be similar to Collings Ranch Conglomerate (Ada Formation). This is a formation that is not mapped in the park but is found in other areas between the Deese Group and the Vanoss Conglomerate. On the eastern part of this locality fossilized wood, brachiopods and fossil hash containing cirripedia (barnacle) plates, stalked echinoderm columnals, and bryozoans were found but these were found washed up onto the shore and cannot be attributed to a specific unit of provenance. The Deese Group exposures on the western and central parts of the locality preserve brachiopods, echinoderm stems and a bryozoan within the matrix of the conglomerate facies (Figure 5). An archeological artifact was found washed up on the shore at this locality.

CHIC PAL 005

At CHIC PAL 005, the limestone facies of the Deese Group is exposed and there is a small outcrop that is partially overgrown with vegetation. Several brachiopods were found. The fossils had recrystallized to calcite and were badly weathered.

CHIC PAL 006
At this locality, there is an exposure of the Deese Group off of the lake shore. It is mostly composed of light gray to white limestone that is very fractured and weathered. There is fossiliferous hash in the rock, with abundant stalked echinoderm fragments.

CHIC PAL 007
An exposure of the Woodford Shale and a light gray limestone with some chert interpreted to be the Bois d'Arc Formation of the Hunton Group is visible at this locality. The outcrop is a shear cliff only accessible by boat. At this locality, the Bois d'Arc Formation has thick (1 cm diameter) stalked echinoderm stems and fewer brachiopods.

CHIC PAL 011 (Girty's USGS 3981)
This locality has been described to have brachiopods and ostracods, and is the type locality for the ostracod *Sansabella unicornis* (originally known as *Entomis unicornis*) (Girty 1909). It is on the western side of CHIC, 5 km (3 mi) northeast of Dougherty, at what is now the edge of the Lake of the Arbuckles. Elias and Branson (1959) determined this locality is in the Ahloso Member of the Caney Shale. This locality was not found during the 2016 survey, so has been determined to be submerged under the lake.

CHIC PAL 012 (AMNH 425)
Zidek (1972, 1975) described an undetermined species of an acanthodian from this locality. It was found in the Caney Shale and is now submerged under the Lake of the Arbuckles.

CHIC PAL 013 (USGS Locality 3914)
This locality is submerged under the Lake of the Arbuckles. A slab of unidentified fossils (Specimen 8903) was reported from the Caney Shale.

CHIC PAL 014 (USGS Locality 3915)
The brachiopod *Productus* (Specimen 8904) and the foraminifera *Fusulina* (Specimen 8905) were reported from the Caney Shale. Although originally identified as the Caney Shale, the exposure may actually be a part of the Deese Group. The Pennsylvanian Deese Group is mapped in that area (Blome et al. 2013) and *Fusulina* is a Pennsylvanian genus, suggesting that a taxonomic or geologic misidentification occurred when the locality was originally defined.

Eastern Boundary of CHIC

CHIC PAL 008
This locality has an exposed ridge of Viola Group with north-dipping beds. The two formations are present in the area—chert-rich, light gray and pink fine-grained limestone of the Viola Springs Formation and coarser limestone that weathers to a darker gray of the Welling Formation. Both lithofacies are fossiliferous with brachiopods and stalked echinoderm columnals. The preservation of the fossils is mostly poor which makes identification difficult. Moving to the northwest, fossil occurrences decrease.

CHIC PAL 015 ("Veterans Lake" Echinoderm Locality)

Despite the name, it is not particularly close to Veterans Lake (the name is borrowed from an adjacent locality discussed in Fay et al. [1982], just outside of CHIC). An outcrop of the Welling Formation is very fossiliferous. Fossil hash is composed primarily of stalked echinoderm columnals with fewer brachiopods and trilobites. Although the fossils are most often preserved as groups, individual fossils are also found throughout the formation. Just north of the Welling Formation is an outcrop of Viola Springs Formation which has an abundance of trilobites, particularly *Cryptolithoides*. Although the Bromide Formation is mapped at this locality, it could not be located during the 2016 fossil survey, due to dense vegetation.

*CHIC PAL 016 (*Quisquilites *type locality)*

This locality was described by Wilson and Urban (1963) as Woodford Shale. Acritarchs, the prasinophyte alga *Tasmanites*, plant spores and the type specimen of *Quisquilites buckhornensis* were described (Wilson and Urban 1963).

Paleontological Resources Directly Around CHIC

Bryozoan Reef Outcrop

Located NW¼ of Section 11, T. 1 S, R. 3 E and the southern half of Section 3, T. 2 S, R. 3 E is a bryozoan reef outcrop which was described by Werts et al. (2001) as being fossilized in situ and includes 120 colonies of 21 species. Fay et al. (1982) reported bryozoans, brachiopods, rhombiferan cystoids, paracrinoids, crinoids, and echinoderm holdfasts in the Mountain Lake Member, and bryozoans and echinoderms in the Pooleville Member. The paracrinoid *Oklahomacystis spissus* was discovered at this locality from the Mountain Lake Member (Frest et al. 1980).

Bromide/Viola Road Outcrop

A second road outcrop is located southeast of CHIC on the eastern side of Highway 177 near Goddard Youth Camp Road. It consists of the Viola Springs Formation on top of the Bromide Formation. There are abundant brachiopods, trilobites, stalked echinoderms, and burrows found in the Bromide Formation.

Buckhorn Asphalt Quarry

East of CHIC is the Buckhorn Asphalt Quarry, located SE ¼, Section 23, T. 1 S., R. 3 E. The fossils are in the Deese Group (Chaplin 1989). The site is notable for abundant molluscan fauna that have preserved their original aragonitic shells, color patterns, and luster. Straight-shelled nautiloids are notably abundant (Chaplin 1989). Other fossils found include rugose corals, bryozoans, chaetetid sponges, brachiopods, ostracods, and echinoderms (Tweet et al. 2015).

Hunton Anticline Quarry

Directly south of the Lake of the Arbuckle dam is the Hunton Anticline Quarry, located at the crest of the Tishomingo Anticline, SE¼ SE¼ NW¼ of Section 31, T. 1 S, R. 3 E. The quarry was opened to provide building materials for the Arbuckle Dam in the mid-1960s (Stanley 2013). The Haragan Formation and both members of the Bois d'Arc Formation are present at the locality. The Cravatt Member contains bryozoans, brachiopods, crinoids, and burrows, and the Fittstown Member has rugose corals, brachiopods, trilobites, and crinoids (Stanley 2001).

Tishomingo Anticline

Graptolites, trilobites, and sponge spicules are known from the Tishomingo Anticline south of CHIC near the M10 locality (Glaser 1965). It is composed of the Viola Group, Sylvan Shale, Hunton Group, and Woodford Shale (Tweet et al. 2015).

White Mound

White Mound is a popular site for fossil hunting in the area. It is located NW ¼ NE ¼ Section 20, T. 2 S, R. 3 E. It consists of the Bois d'Arc, Haragan, and Henryhouse formations. It is notably the type locality for the Haragan Formation. Chaplin (2005) reported foraminifera, sponges, corals, bryozoans, brachiopods, bivalves, nautiloids, trilobites, ostracods, conodonts, and burrows.

Paleontological Resource Management

National Park Service Policy

Fossils are non-renewable resources that offer opportunities for education and scientific discovery. They must be protected on federal land and specific monitoring steps are required to ensure their survival. In 2009, the Paleontological Resources Preservation Act was passed as the primary authority for the protection, management, collection, permitting, and interpretation of fossils.

National Park Service Management Policies state: "Management actions will be taken to prevent illegal collecting [of fossil resources] and may be taken to prevent damage from natural processes such as erosion. Protection may include construction of shelters over specimens for interpretation in situ, stabilization in the field or collection, preparation, and placement of specimens in museum collections. The locality and geologic data associated with a specimen will be adequately documented at the time of specimen collection. Protection may also include, where necessary, the salvage collection of threatened specimens that are scientifically significant."

Baseline Paleontological Resource Inventories

A baseline inventory of the paleontological resources is critical for an effective monitoring report, as it provides information for decision-making. This inventory report compiled information on previous paleontological research done within CHIC, taxonomic groups that have been reported, and localities that were not previously reported on or are no longer available. This report can be a baseline source of information for future research, inventory reports, monitoring and paleontological decisions. The Paleontological Resource Inventory and Monitoring report for the Southern Plains Network done by Tweet et al. (2015) and the references cited within were important baseline paleontological resource data sources for this CHIC-specific report. The United States Geological Survey (USGS) has a recently updated geologic map of the area (Blome et al. 2013) which also provided essential information.

Recommended Paleontological Resource Monitoring

The two biggest threats for the paleontological resources within CHIC are illegal collecting and natural forces, such as erosion. CHIC needs to develop a plan to regularly monitor the paleontological resources within the park and increase awareness of their importance.

Resource Management should develop a paleontological resource monitoring plan or strategy to assess the stability and condition of CHIC fossil localities (Santucci and Koch 2003; Santucci et al. 2009). Paleontological resource monitoring would entail the documentation of weathering, erosion, unauthorized collecting by visitors, and conditions of the rock and fossils. All fossils should be left in place and repeat photo-documentation should be conducted. Photos taken should be stored in an archival storage facility labeled with the location, date, identification if possible, and name of the photographer. Repeat photography is an efficient approach to monitoring long-term changes and does not require a specialist if one is not available.

Monitoring would be most effective in the late winter/early spring while vegetation is sparse and localities are easily accessible. At these times, further surveying can also be completed of areas that were inaccessible during the summer 2016 field survey.

Fossil resources near lake shores are threatened by hydraulic events. Those that are present near the lakes should be monitored several times a year, particularly when the water is at low levels and more rock is exposed. The average water level of the Lake of the Arbuckles was 266 m (873 ft) during the 2016 field survey. Significant change in water level can potentially expose more fossils. If the water level decreases enough, previously documented sites may become accessible once again. Photo-documentation should be used to monitor the effects of the water. Any future construction, e.g. dams or man-made bodies of water, should be documented and photos should be taken of fossil localities before and after the construction.

It is recommended that a geological hazards analysis be conducted at the M10 locality at Goddard Youth Camp because of the slump following the flooding in May 2015 (Figure 9). The area is currently blocked off, but is still easily accessible and dangerous. This area has been a significant locality for paleontological research and would be an ideal area for future research and surveys if it is deemed to be safe again.

Figure 9. Looking north at the M10 locality. The slumped portion is visible on the left. Sediment also slumped in the center of the section, but to a lesser degree (NPS Photo).

Recommended Paleontological Resource Management Actions

It is recommended that for the recreation area's New Employee Orientation, the resource management section be updated to include a statement about managing paleontological resources.

Fossil localities should not become public knowledge and should be limited to management staff and those directly involved in monitoring to increase protection against fossil theft.

Interpretive staff should be trained to recognize common fossils in the park and should be educated on proper procedures when coming across them. When a fossil is found, Resource Management should be informed of the locality, a photo should be taken by the individual who discovered it, and the fossil should be left where it was found.

Law Enforcement staff should become familiarized with fossil localities within the park in order to monitor and protect from fossil theft and vandalism. Many of the fossil localities in the park are off-road, which makes them less vulnerable to theft, but the easily accessible localities need increased monitoring.

Proper curation and storage of the specimens held within the park is recommended, including catalog numbers, photographs, and entering data into Re:discovery. Documentation of CHIC specimens held in repositories should also be obtained and included in the park's database. Specimens already stored in CHIC which lack proper information (e.g. locality) should be curated and potentially used for educational purposes.

Staff should educate visitors on the NPS regulations regarding fossils. A system needs to be developed on how to handle paleontological resources that visitors turn in from the park. Information about the locality, date, and name and contact of the person who found it needs to be recorded, Resource Management should be informed, and the specimen should immediately be catalogued in the museum collections.

Research

Permit System

Permits are required for research and collection in any national park unit. The permit documents the purpose of the research, allows the park to place limits on the researchers in order to protect resources, and serves as a record for the park. The park should obtain copies of field notes, photographs, samples collected for the research and the final report. Information on how to obtain a permit can be found at the U.S. National Park Service Research Permit and Reporting System: http://irma.nps.gov/rprs/.

Current Research

There is currently no paleontological research being conducted on the fossils found within Chickasaw National Recreation Area. There is ongoing geological research being done within the Arbuckle Mountains, but none of the studies are actively within or in the immediate vicinity of CHIC and none are known to be paleontological.

Throughout the year, geology students from the University of Oklahoma and Oklahoma State University visit the Arbuckle Mountains and CHIC to learn about the geology and practice field techniques. Geology students from the University of Mississippi visit CHIC each summer to practice describing and identifying lithologies, mostly on the northeastern side of the park.

Past Research

Since 1909, research has been published on specimens from what is now Chickasaw National Recreation Area. Extensive work has been conducted in the area; however, the scope of research encompasses more than CHIC, investigating the Arbuckle Mountains or the fauna of a specific stratigraphic formation. For example, a publication such as Alberstadt (1973), "Articulate brachiopods of the Viola Formation (Ordovician) in the Arbuckle Mountains, Oklahoma", reports on fossils from multiple sites including a locality in CHIC. CHIC itself was not established until 1976, so no reference older than this will use that terminology. Therefore, some approximation was used for determining if references pertain to localities and specimens within the boundaries of CHIC.

From those references attributed to CHIC, the majority of the research focused on brachiopods. Even when other fauna were found in the same stratigraphic unit, they were often not collected and the author listed generic and species level designations for only the brachiopods. A few studies have been conducted specifically on the trilobites in the area and fewer still on the echinoderms and bryozoans. For specific authors who conducted past paleontological research in CHIC, see citations within the Paleontological Resource Inventory section.

Proposed Research Topics

In the Welling Formation at the "Veterans Lake" echinoderm locality, there is an abundance of stalked echinoderm columnals that have a unique bead-shape with moniliform latera (having convex outer facing sides with a circular transverse section), but which are not easily identifiable due to lack of information (Figure 10). There is no known publication involving this location and its fauna. Further mapping of this area would also be helpful to determine exactly how many units are exposed.

Currently multiple formations are mapped as undifferentiated from one another making it difficult to determine the unit of provenance for many fossils.

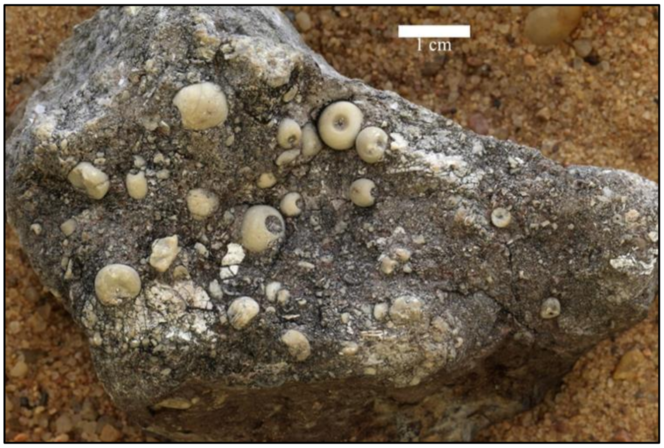

Figure 10. Unidentified stalked echinoderm columnals from the Welling Formation of the Viola Group of the "Veterans Lake" echinoderm locality. Photo by Roger Burkhalter.

The M10 site is a very fossiliferous outcrop of the Hunton Group, and most of the publications discussing this area are from the 1960s, except for a few over the last two decades. The publications describe the taxa from the different stratigraphic units. Because the Haragan and Henryhouse formations are difficult to distinguish based on lithology, a study can be conducted at this site to compare the fauna (abundance, diversity) across the different formations.

Microfossils and other taxa that have been found in CHIC (Table 1), but were only reported in passing can be further investigated. In the Hunton Group, there have been reports of conodonts, foraminifera, ostracods, and gastropods. The Woodford Shale is reported to have ostracods, plant spores, algae, and acritarchs. The Viola Group, Bromide Formation, and Caney Shale are known to have ostracods, and foraminifera have been reported in the Deese Group. This would further enrich the understanding of what paleontological resources are within CHIC.

A Bromide bryozoan reef area along Highway 177 (just outside of CHIC) has been reported to have several bryozoan species and colonies (Werts et al. 2001). In addition, there are stalked echinoderm columnals, brachiopods, and fossiliferous hash. There are sedimentary features, such as laminated beds, mottling, and different energy environments that can be determined. These different variables give opportunities for several research topics from a paleontological or geological view.

Collections and Museums

CHIC Collections

CHIC has a small museum used for storing historical documents, artifacts, and specimens. The building is secured by a lock and alarm system, and the collections room has temperature and humidity controls. In the past, CHIC fossil collections included at least 36 catalogued fossil specimens, but these were either deaccessioned by 1988 (Tweet et al. 2015) or lost due to flooding. There are currently at least 30 trays of uncatalogued specimens stored, including brachiopods, rugose corals, bryozoans, bivalves, cephalopods, stalked echinoderms, fossil "hash" (pieces of rock with abundant fossil fragments), and wood. There is no information included for any of these specimens. The most recent addition to the specimens is a straight cephalopod turned in by a visitor in March 2015. The locality where it was discovered was recorded and contact information for the visitor was noted but it has not been curated.

The Chickasaw NRA Scope of Collection Statement says "each species found in the park should be represented by the minimum number of specimens required to fully document the horizontal and stratigraphic range of the species and the various habitats in which each species was fossilized" (2010). Seventy-three lots of fossils were accessioned into the museum collections following the 2016 fossil survey in order to meet the minimum level of baseline information required in the NPS Servicewide Standards.

Currently in the Travertine Nature Center, there are several fossils on display. Several were found in Murray County, but it is unknown if they were found within the park: a Viola Group trilobite, *Cryptolithoides ulrichi*; *Oklahomacystis tribrachiatus* paracrinoids from the Bromide Formation; Devonian petrified wood *Callixylon*; a Devonian *Rayonnoceras* nautiloid; and a Devonian *Camarocrinus* crinoid. Fossils on display that were not found within Murray County include a Cretaceous ammonite found in Johnston County; a Jurassic to Eocene-aged bivalve, *Gryphaea*; and an early Cretaceous bivalve, *Pecten*. Stored in the back of the Nature Center are two ammonites and rocks with shell fragments and impressions from unknown localities.

The Goddard Youth Camp's Children's Museum, which is normally closed to the public but available to the campers, houses trilobites, brachiopods, coral, petrified wood, ammonites, full-sized *Acrocanthosaurus* and "raptor" skeletons, and minerals like quartz and barite rose rocks. Goddard Youth Camp historically and currently allows collecting within the park, which is an activity that needs further investigation.

Cultural Resources

At Goddard Youth Camp there are many man-made structures in which fossils have been incorporated. These fossils were collected from localities outside of the park. A wall on the main office building is embedded with fossils (Figure 11). There are several corals, bryozoans, brachiopods, mollusks including ammonites, petrified wood, invertebrate burrows, and fossiliferous hash. The on-site camp director's house has ammonites and petrified wood in part of its foundation. Inside the dining hall, a central chimney and sections of each wall have ammonites, petrified wood, bivalves, stalked echinoderm columnals, corals and fossiliferous hash, in addition to minerals like barite roses, fluorite, gypsum and quartz. The source locality for all specimens is unknown, and many are not known to be found within the recreation area.

Figure 11. Fossils embedded into the wall of the main office building at Goddard Youth Camp. Spiral ammonites are readily apparent, but a close inspection reveals many other fossils (NPS Photo).

In the CHIC area there are many archeological sites. However, most of these sites are now submerged under the Lake of the Arbuckles. The only documented occurrences of archeological and paleontological resources occurring at the same locality was found during the 2016 fossil survey. Along the southern shore of the Lake of the Arbuckles, an arrowhead was found amongst gravel on the beach. At the same site, clasts of fossiliferous hash, most likely from the Welling Formation, were incorporated into the conglomerate facies of the Deese Group. There have been no reports of fossils being incorporated into artifacts, although there is always potential for fossils to be found at archeological sites.

Repositories

There are three repositories holding paleontological specimens from CHIC. They are the Sam Noble Oklahoma Museum of Natural History (SNOMNH; Norman, OK), the National Museum of Natural History (USNM; Washington D.C.), and the American Museum of Natural History (AMNH; New York, NY). Most of the fossils stored at the SNOMNH were collected from the M10 locality (see Amsden 1958b; Sutherland 1965; Campbell 1977) (Appendix C). The Oklahoma Geological Survey (OGS) has also collected specimens which are housed at SNOMNH. The type specimen of the palynomorph *Quisquilites buckhornensis* Wilson and Urban (1963) is stored at SNOMNH as OPC 7026-19036 on slide OPC 7026-19083. USNM is reported to have the specimens described by Girty (1909), which includes the holotype specimen of the ostracod *Sansabella unicornis* (previously known as *Entomis unicornis*) (USNM PAL 120749). It is also probable that specimens collected for the U.S. Geological Survey (USGS) are at USNM. The acanthodian reported by Zidek (1972, 1975) from the Caney Shale is stored at AMNH (AMNH 425). OGS and USGS may have records of collected specimens (Tweet et al. 2015).

Recommendations for Specimen Storage

Uncatalogued specimens held within CHIC should be curated and can then be offered to the Interpretation Division for educational purposes. All future specimens need to be accompanied with complete and accurate descriptions and should be immediately recorded, entered into the park's database and curated. Vital information includes geographic and stratigraphic location, identification, field number, date of collection and collector. A paleontological locality form (PLF) was created for CHIC to standardize the information collected (Appendix D). The form contains locality information as well as a lithologic description, location of field notes and photographs, and information on site access, locality condition, and fossil occurrence/condition. The PLF should be accessioned into the museum collections along with any field notes and photographs to ensure that all data are preserved.

CHIC PaleoBlitz & Fossil Festival

On May 20, 2016 Chickasaw National Recreation Area hosted the first National Park Service PaleoBlitz as part of the NPS centennial celebrations. The PaleoBlitz was a day of discovery where a field team surveyed known localities within CHIC in an effort to gather as much data on the park's fossil resources. The following day was a fossil festival, a public event where visitors learned about the paleontological resources in CHIC and the information gathered during the PaleoBlitz. Visitors also learned about the importance of preserving fossils in the national parks and the public's role in protecting them. CHIC interpretive staff participated in the event and were able to familiarize themselves with the fossils in the park as well as educate the public on general paleontology (see Interpretation section). A video was created highlighting these events and was featured along with three other parks who hosted BioBlitzes (https://www.youtube.com/watch?v=uE04zpxwsKo).

CHIC was chosen to host the first NPS PaleoBlitz because of its potential for scientific discovery and educational outreach. A previously published natural resource report by the Southern Plains Network identified CHIC as having great potential for paleontological resources but little work had been done to document the fossils. The PaleoBlitz provided a start to this inventory report as many specimens were documented and collected (see Paleontological Resource Inventory section) at previously reported localities as well as finding one new locality. CHIC was also an ideal host because Park staff were very enthusiastic about expanding their knowledge of the resources and educating the public on any findings. The education and outreach was made easier by CHIC's partnership with Goddard Youth Camp, which provided a great setting due to their existing paleontology education activities.

Interpretation

Current Interpretive Use of Fossils

The Travertine Nature Center provides education on the natural resources of the recreation area but this is primarily limited to geology and wildlife. There are no lesson plans or interactive exhibits on the paleontological resources. There is one case that contains eight fossils. Five of the fossils are from Murray County, but it is not stated if they were collected within CHIC. The fossils from Murray County are *Rayonnoceras*, *Callixylon*, *Cryptolithoides ulrichi*, *Oklahomacystis tribrachiatus*, and *Camarocrinus*. Fossils of *Gryphaea*, *Pecten*, and Cephalopoda are also on display but are not found anywhere within CHIC. There is a small sign explaining that the above organisms used to live in the area. Besides the case, there are a few fossils that are stored for potential educational use, but none of these fossils can be found in the recreation area. Currently, interpretive staff are not trained to identify and teach about fossil resources within CHIC and they are unaware of the locations where these resources can be found. The Interpretive staff are very interested in learning about CHIC's fossils and expanding their interpretive themes to include paleontological resources.

Junior Paleontologist Program

Visitors to CHIC can participate in the Junior Paleontologist Program – children receive booklets filled with activities and facts about paleontology and when complete they are sworn in as junior paleontologists and receive a badge. The Junior Paleontologist Program was first used by interpretive staff during the Chickasaw National Recreation Area PaleoBlitz & Fossil Festival.

Recommendations for Interpretation

Although there are abundant fossils within CHIC, most visitors and staff are unaware of these resources. Fossils fascinate people of all ages and spur many to careers in science. The incorporation of paleontology themes into the existing interpretive plan for the recreation area would greatly enrich visitor experiences. The integration of paleontological education can be built into CHIC's existing Primary Interpretive Theme A:

> "Chickasaw National Recreation Area's 500-million-year record of sedimentary deposition, complex hydrogeological system, and diverse flora and fauna foster enriched connections with the dynamic relationships among geology, water, and life" (NPS 2008).

Before any interpretive themes or lesson plans can be enacted, it is essential that the interpretive staff learn about the fossils found within CHIC. This includes:

- Where the fossils are located
- The taxonomic groups present and how to identify them
- What should be done if a fossil is found within the recreation area (see Paleontological Resource Management section)

It is recommended that the uncatalogued fossils, with no information, stored in the museum collections should be used for educational purposes. While not all of these fossils can be found in the park, they can be used in different interpretive themes that are about general paleontology rather than park specific themes. During the fossil survey, specimens were collected specifically for use by interpretive staff. These fossils include brachiopods, stalked echinoderms, and fossil hash that are commonly found within CHIC. Having these specimens will help to quickly familiarize staff with the park's paleontological resources. These fossils and the following interpretive themes can also be used by staff to create activities and events for NPS's National Fossil Day (http://nature.nps.gov/geology/nationalfossilday/)

The display case that is currently in the Travertine Nature Center should be updated to include text stating whether or not a fossil can be found in the recreation area. Specimen text should also include common names in addition to the scientific names already listed. An alternative is to only display fossils that are found within CHIC. The fossils collected during the survey can be easily incorporated into a display and have all the necessary information for exhibit text. Visitors would get a fuller picture of the ancient life that lived in the area and this would connect better to the interpretive theme of recreating CHIC's paleoenvironment.

The final way that paleontology can be easily incorporated into the Nature Center's existing displays is at a small interactive station for children. There are objects related to CHIC's wildlife that children can touch and draw. A slab of fossil hash can be bolted to the station for visitors to get a closer look at and feel for themselves. Pictures of crinoids, brachiopods and trilobites can also be added for children to color.

Proposed Interpretive Themes

There are many possible themes that the interpretive staff can use to inform the public on the paleontological resources within the recreation area. The four themes that would be most easily employed by interpretive staff are drafted in detail below. Other themes that can be developed if there is a high demand for paleontology education include: Evolution and Geologic Time, Public Misconceptions about Paleontology, and Media Misinformation.

What are fossils?

- Fossils are the remains of past life. They can be body fossils, preserving the actual organism, or trace fossils, preserving what they left behind (i.e. footprints). Shells and bones preserve while soft tissue decomposes.
- After an organism dies, if it is lucky, it will be buried in sediment. Water flows through the sediment or rock and slowly replaces the minerals in the bone (or shell) with different minerals. Over millions of years, the entire bone is replaced, turning it into a rock.
- The sediment that buries an organism can eventually be compacted into rock and these rocks are called sedimentary rocks. Examples of sedimentary rocks are sandstone and shale. Paleontologists look for fossils in sedimentary rocks because fossils would be destroyed in other types of rock (igneous or metamorphic). So paleontologists do not look for fossils in granite or schist.
- In CHIC these units are the Viola Group, Hunton Group, and Caney Shale.
- When paleontologists are out in the field, their most important tool is a geologic map. Fossils are more common in certain sedimentary rocks, so knowing where these units are exposed is important. Other tools that paleontologists use are field books, brushes, picks, hand lens, sample bags, GPS, camera, topographic maps, a special glue-like substance, and First Aid and Safety equipment.
    - Having examples of these materials during the talk would be very helpful.
- If fossils are found in the park, visitors should photograph it and notify a ranger of its location. Most importantly, they should leave the fossil where they found it.

Why are fossils important?

Biostratigraphy & Age Dating

- A single rock unit may only be exposed on the surface a few places within a large area. By looking at the fossils within the rocks, paleontologists can match layers of rock that have the same fossils in them. These rock units were deposited at the same time.
- Some fossils only existed for a short period of time. These are called index fossils. If these fossils are found in a rock layer and we know the age of the fossil, we will also know the age of the rock.

- Ammonites only existed during the Mesozoic Era (250–65 Ma). So, any rocks that contain ammonites will be Mesozoic in age. Ammonites at Lake Texoma have helped date the rocks there to 145–65 million years old (Cretaceous).

Comparing Fossils with Modern Animals

- Paleontologists can compare life habits (e.g. swimming, burrowing) of modern animals to fossilized ones to figure out how they lived.
- Trilobites are an extinct group of arthropod. Some modern arthropods, like horseshoe crabs, gather to molt and mate. From this, paleontologists determined that trilobites probably did the same thing based on rocks that preserve dense populations of trilobites.

Reconstructing Paleoenvironments

- Paleontologists often look at all of the flora and fauna preserved in a rock unit. From this, they are able to recreate past ecosystems. Using both fossil evidence and comparisons with modern analogs, paleontologists can also determine how these organisms interacted with each other.
- This technique can be used for many different areas of successive rock units. Then, paleontologists can compare these and see how ecosystems have changed through time. Although south-central Oklahoma is now a grassland, 400 million years ago this used to be a marine environment. We know this because of the fossils that are found within the recreation area and in the Arbuckle Mountains.
    - Use of fossils would be very helpful for this section to show visitors the marine life that used to live in the area.

Predict the Future

- Paleontologists study past events to help figure out what can happen in the future. This allows for better prediction of how organisms will respond (geographic range shifts, extinctions, adaptations) to changes in their environment.
- In the geologic past, times of global warming (e.g. Permian Period) have led to ocean acidification and mass extinctions (e.g. Late Permian mass extinction). The Earth is experiencing similar situations now with climate change, rising temperatures and increases in the rate of extinctions.

Paleontology vs. Archeology

- People often mix up paleontology and archeology. Although both disciplines study ancient history and dig up objects from the ground, there are many important differences.
- Paleontology is the study of past plant and animal life that is preserved as fossils. Many paleontologists are also geologists because they need to know about how rocks form and preserve fossils. This does not include human remains (Anthropology). Archeology is the study of past human cultures, and in Oklahoma, Native American archeological studies are very popular.

- George Cuvier is the father of paleontology. Other famous paleontologists include Jack Horner and Dr. Scott Sampson (Dinosaur Train). Fictional paleontologists include Alan Grant and Ellie Sattler from Jurassic Park and Ross Geller from Friends.
- The most famous fictional archeologist is Indiana Jones.

Threats to Fossils

- Erosion by wind and water is the most prevalent cause of fossil damage/loss. When fossils are eroded from the rock they can be broken, separated or completely destroyed over time. Paleontologists monitor important fossil localities to document fossils that many be lost due to erosion.
- The presence of wildlife can also damage fossils. Some fossil localities are on ranches where grazing cattle can step on and destroy fossils. Plants can also destroy fossils because their roots can grow down into the soil through the fossils and break them apart.
- Theft of paleontological resources prevents researchers from finding and studying fossils. In the National Park Service, it is illegal to take fossils from any park land. Fossils are nonrenewable resources and they should be available for everyone to see and study.
- Sometimes, a site is very important and scientists want to take all of the fossils and put them in a museum to protect them from the above threats. However, if all of the fossils are taken, nothing will be left in its original context for study. That site will also lose importance, because the resources that were there are now gone. This has happened in the past and led to the decommissioning of a national monument (e.g. Fossil Cycad National Monument, South Dakota) (Santucci and Ghist 2014).

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Appendix A: Specimens Collected During 2016 Survey

List of specimens collected during the fossil survey of summer, 2016 arranged by locality, formation and then alphabetically by type. An asterisk (*) denotes a specimen that has not been previously identified within CHIC.

Locality	Formation	Type	Identification	Quantity
CHIC PAL 001	Henryhouse-Haragan	brachiopod	*Atrypa oklahomensis**	2
	Henryhouse-Haragan	brachiopod	*Dicoelosia varica*	1
	Henryhouse-Haragan	brachiopod	*Kozlowskiella* (*Megakozlowskiella*) *velata*	2
	Henryhouse-Haragan	brachiopod	*Leptaena acuticuspidae*	5
	Henryhouse-Haragan	brachiopod	*Levenea subcarinata pumilis*	3
	Henryhouse-Haragan	brachiopod	*Meristella atoka*	1
	Henryhouse-Haragan	brachiopod	*Obturamentella*? *wadei*	1
	Henryhouse-Haragan	brachiopod	*Orthostrophia strophomenoides*	2
	Henryhouse-Haragan	brachiopod	*Cf. Rensselaerina*	1
	Henryhouse-Haragan	brachiopod	*Rhipidomelloides oblata*	3
	Henryhouse-Haragan	brachiopod	*Schuchertella attenuata**	1
	Henryhouse-Haragan	brachiopod	*Sphaerirhynchia ?lindenensis*	2
	Henryhouse-Haragan	bryozoan	*Cyphoytrypa corrugata*	6
	Henryhouse-Haragan	bryozoan	*Stromatotrypa* sp.*	2
	Henryhouse-Haragan	bryozoan	Encrusting bryozoan	1
	Henryhouse-Haragan	coral	Rugosa	3
	Henryhouse-Haragan	echinoderm	Calyx piece	1
	Henryhouse-Haragan	echinoderm	Stalked echinoderm columnals	5
	Henryhouse-Haragan	trilobite	*Reedops deckeri*	1
	Henryhouse-Haragan	trilobite	Thorax, pygidium; gen. et sp. unknown	3
CHIC PAL 002	Bois d'Arc	echinoderm	Stalked echinoderm columnals*	4
	Haragan	brachiopod	*Levenea subcarinata pumilis*	1
	Haragan	brachiopod	*Sphaerirhynchia lindenensis*	2
	Haragan	coral	Rugosa	1
	Haragan	hash	Stalked echinoderm columnals, bryozoan fragments	1
	Haragan	trilobite	*Cf. Kainops raymondi*	1
	Haragan	trilobite	Pygidium; gen. et sp. unknown	1
CHIC PAL 004	Deese	brachiopod	*Orthostrophella? clarensis**	1
	Source unit unknown	brachiopod	*Diceromyonia cf. D. tersa*	1
	Source unit unknown	echinoderm	Stalked echinoderm bulb	1
	Source unit unknown	hash	Coquina (biosparite)	1
	Source unit unknown	plant	Fossilized wood	2

Locality	Formation	Type	Identification	Quantity
CHIC PAL 009	Henryhouse-Haragan	brachiopod	*Lissostrophia ?cooperi*	1
	Henryhouse-Haragan	brachiopod	*Meristella atoka*	5
	Henryhouse-Haragan	brachiopod	*Cf. Orbiculoidea**	2
	Henryhouse-Haragan	brachiopod	*Orthostrophia strophomenoides*	3
	Henryhouse-Haragan	brachiopod	*Ptychopleurella ?rugiplicata**	1
	Henryhouse-Haragan	brachiopod	*Rhipidomelloides oblata*	1
	Henryhouse-Haragan	brachiopod	*Rhynchospirina maxwelli*	2
	Henryhouse-Haragan	bryozoan	*Cyphotrypa corrugata*	4
	Henryhouse-Haragan	bryozoan	*Stromatotrypa* sp.*	2
	Henryhouse-Haragan	coral	Rugosa	3
	Henryhouse-Haragan	echinoderm	Echinoderm stem fragment	1
	Henryhouse-Haragan	nautiloid	*Orthoceras**	1
	Henryhouse-Haragan	trilobite	Pygidium; gen. et sp. unknown	2
	Henryhouse-Haragan	trilobite	*Huntonia* sp.	1
	Henryhouse-Haragan	trilobite	*Kainops raymondi*	2
CHIC PAL 010	Welling	nautiloid	*Orthoceras**	1
	Welling	echinoderm	Stalked echinoderm columnals	1
	Source unit unknown	brachiopod	Lingulid	1
CHIC PAL 015	Welling	brachiopod	*Austinella* sp., trilobite cephalon	1
	Welling	brachiopod	*Austinella* sp., *Lepidocyclus cooperi*	1
	Welling	brachiopod	*Lepidocyclus cooperi*	2
	Welling	brachiopod, hash	*Lepidocyclus oblongus**, crinoidal hash	1
	Welling	echinoderm	Echinoderm stalk	1
	Welling	echinoderm	Crinoid columnals	21
	Welling	hash	Crinoidal, brachiopodal, with possible trilobite hash	2
	Welling	nautiloid	*Orthoceras**	1
	Welling	trilobite	Pygidium; gen. et sp. unknown	2
	Viola Springs	trace fossil	Burrows	1
	Viola Springs	trilobite	*Cryptolithoides ulrichi**	5

Appendix B: Repository Contact Information

American Museum of Natural History (AMNH)
Central Park West @ 79th Street
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Contact: Ruth O'Leary
Director of Collections, Archives and Preparation
Division of Paleontology
oleary@amnh.org

Sam Noble Oklahoma Museum of Natural History (SNOMNH)
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Smithsonian National Museum of Natural History (USNM)
10th and Constitution Ave.
Washington, DC 20560-0121
Contact: Kathy Hollis
Collections Manager
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Appendix C: Specimen Lists from Repositories

Sam Noble Oklahoma Museum of Natural History: Specimens from the M10 locality held in the Invertebrate Paleontology Collections at the SNOMNH. Organized by taxonomic group.

Common Name	Scientific Name	Specimen Number(s)	Quantity	Formation
Coral	*Pseudocryptophyllum* sp. *A*	OU 5546	1	Henryhouse
Brachiopod	*Artiotreta parva*	OU 4741a, 4741b	2	Clarita
	Atrypa tennesseensis	OU 123552–123562, OU 22903	12	Henryhouse
	Brachyprion attenuata	OU 22912	1	Henryhouse
	Delthyris sp.	OU 22904	1	Henryhouse
	Leptaena sp.	OU 22905	1	Henryhouse
	Lissatrypa decaturensis	OU 123563, OU 22906	2	Henryhouse
	Lissostrophia cooperi	OU 123564, OU 22907	2	Henryhouse
	Parmorthis brownsportensis	OU 123565–123568, OU 22908	5	Henryhouse
	Calymene clavicula	OU 6184	1	Henryhouse
	Anastrophia grossa	OU 123572, OU 123668–123671, OU 22925, OU 22948	7	Haragan
	Atrypa oklahomensis	OU 123672–123681, OU 22949–22950	12	Haragan
	Atrypa sp.	OU 22914	1	Haragan
	Atrypina hami	OU 123573–123574, OU 123682–123684, OU 22926, OU 22951	7	Haragan
	Chonostrophia helderbergia	OU 3627	1	Haragan
	Coelospira virginia	OU 22954–22955	2	Haragan
	Cyrtina dalmani nana	OU 123575–123577, OU 22928–22931	7	Haragan
	Delthyris velata	OU 123578–123586, OU 123731–123735, OU 22920, OU 22932, OU 22974	17	Haragan
	Isorthis pygmaea	OU 1117, OU 22934, OU 22958	3	Haragan
	Howellella cycloptera	OU 22957	1	Haragan
	Leptaena acuticuspidata	OU 123685–123691, OU 22959	8	Haragan
	Leptaenisca concava	OU 22960	1	Haragan
	Levenea subcarinata pumilis	OU 123569–123570, OU 123587–123590, OU 123692–123697, OU 22922, OU 22936, OU 22961	15	Haragan
	Lissatrypa sp.	OU 22916	1	Haragan
	Obturamentella wadei	OU 22937	1	Haragan
	Orthostrophia strophomenoides parva	OU 123591–123615, OU 123667, OU 22938, OU 22947	28	Haragan
	Rensselaerina haraganana	OU 1004, OU 123698–123705, OU 22963–22964	11	Haragan
	Rhipidomella oblata	OU 123616–123641, OU 123706–123718, OU 22924, OU 22939–22940, OU 22965	43	Haragan
	Rhynchospirina maxwelli	OU 123642–123657, OU 123719–123724, OU 22941, OU 22966	24	Haragan
	Schuchertella haraganensis	OU 22967	1	Haragan
	Sphaerirhynchia glomerosa	OU 123658–123661, OU 22942, OU 22968	6	Haragan

Common Name	Scientific Name	Specimen Number(s)	Quantity	Formation
Brachiopod	*Strophodonta arata*	OU 123665–123666, OU 22945, OU 22972	4	Haragan
	Strophodonta gibbera	OU 123662–123664, OU 123729–123730, OU 22918, OU 22944, OU 22970–22971	9	Haragan
	Meristella atoka	OU 1189, OU 123571, OU 22923	3	Haragan-Bois d'Arc
	Sphaerirhynchia lindenensis	OU 123725–123728, OU 123736, OU 22943, OU 22969, OU 22976	8	Haragan-Bois d'Arc
	Strophonella bransoni	OU 22946, OU 22973, OU 22978	3	Haragan-Bois d'Arc
	Howellella cyclopterus	OU 123737–123738, OU 22977	3	Bois d'Arc
	Rhipidomelloides oblata	OU 22975	1	Bois d'Arc
	Coelospira saffordi	OU 123551, OU 22902	2	Buckhorn
Ostracod	*Parabolbina scotti*	OU 5976	1	Haragan
Trilobite	*Ananaspis guttulus*	OU 55419, OU 6201	2	Henryhouse
	Kainops raymondi	OU 6818	1	Haragan
	Kainops invius	OU 7214	1	Bois d'Arc

National Museum of Natural History: Specimens held in the Invertebrate Paleontology Collections at the NMNH. Organized by taxonomic group. An asterisk (*) indicates specimens whose longitude and latitude are within CHIC. The others are directly around CHIC and have a locality uncertainty radius that overlaps within park boundaries. A dagger (†) denotes a holotype specimen. Information provided with the permission of the National Museum of Natural History, Smithsonian Institution, 10th and Constitution Ave. N.W., Washington, DC 20560-0193. (http://www.nmnh.si.edu/)

Common name	Scientific Name	USNM Paleo Catalog Number	Quantity	Formation
Brachiopod	*Acanthocrania subquadrata*†	109759	5	Bromide
	Glyptorthis crenulata	110054	1	Bromide
	Doleroides compressus	110596	2	Bromide
	Doleroides compressus	110605	1	Bromide
	Doleroides compressus†	110607	6	Bromide
	Glyptorthis crenulata†	116932	3	Bromide
	Chaulistomella mundula†	117000	3	Bromide
	Doleroides oklahomensis	117033	9	Bromide
	Protozyga costata	117239	3	Bromide
	*Productella hirsutiformis**	183589	1	Caney
Echinoderm	*Sinclairocystis praedicta**	241274	1	-
Ostracode	*Entomis unicornis*†*	120749	1	Caney
	*Cytherella aff. benniei**	120750	1	Caney
Trilobite	*Cryptolithoides fittsi*	454970	1	-
	Cryptolithoides fittsi	454972	1	-
Plant	Gen. sp. fossilized wood*	349172	1	-
Unknown	Various unidentified specimens*	USNM LOC 2194	1	Bromide
	Various unidentified specimens*	USNM LOC 24050	1	Bromide
	Various unidentified specimens*	USNM LOC 24096	1	Bromide
	Various unidentified specimens	USNM LOC 24095	1	Bromide
	Various unidentified specimens	USNM LOC 23958	1	Bromide
	Various unidentified specimens	USNM LOC 24841	1	Bromide
	Various unidentified specimens	USNM LOC 23980	1	Bromide
	Various unidentified specimens	USNM LOC 2167*1	1	Bromide
	Various unidentified specimens	USNM LOC 2167B	1	Bromide
	Various unidentified specimens	USNM LOC 24093	1	Bromide
	Various unidentified specimens	USNM LOC 2212	1	Bromide
	Various unidentified specimens	USNM LOC 38285	1	Haragan
	Various unidentified specimens	USNM LOC 29447	1	Hunton Group
	Various unidentified specimens	USNM LOC 2199A	1	McLish
	Various unidentified specimens	USNM LOC 24016	1	McLish
	Various unidentified specimens	USNM LOC 24005	1	Viola Group

Common name	Scientific Name	USNM Paleo Catalog Number	Quantity	Formation
Unknown	Various unidentified specimens	USNM LOC 23938	1	Viola Group
	Various unidentified specimens	USNM LOC 24139	1	-

Appendix D: Paleontological Locality Form

Chickasaw National Recreation Area

Locality Number: ___CHIC PAL ###___ Locality Name: ______________________________

Field Number: ______________________ Other Number: _______________________________

1. Type of Locality: Invertebrate ____ Plant ____ Vertebrate ____ Trace ____ Other ____

2. Group: ________________ Formation: ___________________ Member: __________________

3. Age: Period: ____________ Series: ______________________ Stage: __________________

4. Location of Outcrop: Lat/Long __________________N _________________W (WGS 1984)

5. Position source: GPS___ File: ___ Derived from topography ___ Estimated from memory ___

6. USGS Quad Name: ___________ Scale: _____min. Edition: ______

7. County: __Murray__________ State: ____OK________

8. Lithology:

____

____

____

9. Ownership: NPS__X__ BLM_____ USFS_____ Private_____
Other_________________

10. Field notes reference:

Name Date

____

____

____

11. Photographs: Digital: ____ Folder name____

Optical: ____ Location _______________________________________

(over)

12. Repository(s) for collected specimens

Name	Place	Contact name/number
Chickasaw NRA	Sulphur, OK	Resource Management Staff

13. Locality recorded by: ______________________________ Date: _____________

14. Site Access: Easy____ Moderate____ Difficult____

15. Locality Condition: Unconsolidated/erodes quickly____
Erosion/fossil exposure w/in a couple years____ Erosion/fossil exposure slow____

16. Fossil Occurrence: Low____ Moderate____ High____

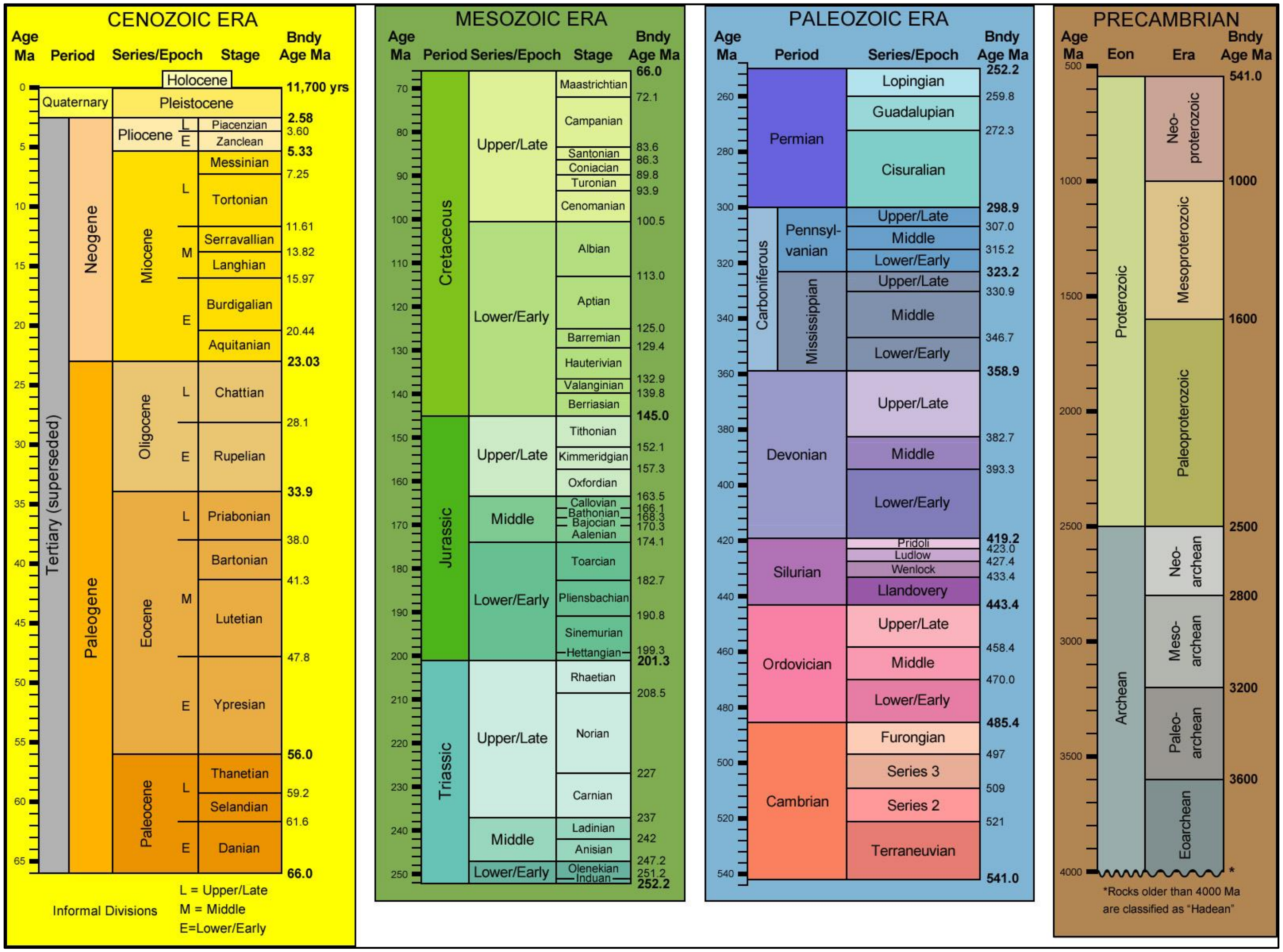
17. Fossil Condition/Preservation: Poor____ Good____ Excellent____

18. Specimens observed/collected (attach list if necessary):

Field #	Taxon	Element	In situ/float	Collected (Y/N)

19. Additional Comments (i.e. mitigation required, site disturbance, etc.):

Appendix E: Geologic Time Scale



Ma=Millions of year old. **Bndy Age**=Boundary Age. Colors are standard USGS colors for geologic maps. Modified from 1999 Geological Society of America Timescale (www.geosociety.org/science/timescale/timescl.pdf). Dates and additional information from International Commission on Stratigraphy update 2014/02 (http://www.stratigraphy.org/index.php/ics-chart-timescale) and USGS Fact Sheet 2007-3015 (http://pubs.usgs.gov/fs/2007/3015/).

NPS 107/133803, August 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

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