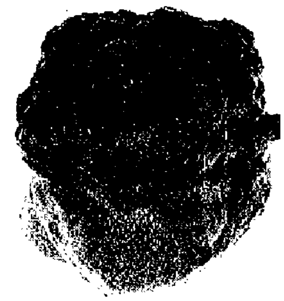
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 45, NO. 5 — OCTOBER 1985

On the cover—



Anomalous Pyrite Nodules on Surface Outcrops of Altered Permian Red Beds in Oklahoma

The photograph on the cover illustrates bleached red-bed sandstones and differentially weathered pyrite nodules on a surface outcrop overlying structurally controlled oil-productive zones in the Loco District in Stephens County, south-central Oklahoma. Pictured above is a close-up view (1 in. in diameter) of a pyrite nodule collected from the outcrop.

Several oil fields in south-central and southwestern Oklahoma are overlain by altered or bleached red-bed strata that commonly contain carbonate and sulfide cements. Distinct color changes occur in the red beds along northwest–southeast-trending lines of production. Extensive mineralogical and chemical diagenesis induced by the seepage of underlying hydrocarbon products and associated gases results in the formation of concentrically zoned aureoles. Zones of diagenetic limestone, bleached sandstone, altered strata with pyrite cement, and unaltered red beds are mappable over these oil fields.

Calcite is the most common diagenetic carbonate product observed; however, iron- and manganese-rich varieties of calcite and dolomite are present. The most common sulfide seen is pyrite, but pyrrhotite, marcasite, galena, and sphalerite also occur in the altered red beds.

Occurrences of pyrite nodules, as shown on the cover, are described in my master's thesis, "Diagenetic Aureoles Induced by Hydrocarbon Migration in the Permian Redbeds of South-Central Oklahoma," which was conducted under the direction of Zuhair Al-Shaieb at Oklahoma State University.

Janet L. Cairns
Amoco Production Co., Tulsa

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Short articles on aspects of Oklahoma geology are welcome from contributors. A set of guidelines will be forwarded on request.

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THE ALLISON/MENIFEE MAMMOTH EXCAVATION: EVIDENCE FOR A LATE PLEISTOCENE STREAM COURSE IN CENTRAL OKLAHOMA

Charles D. Neel[1]

Abstract

In early Spring 1984, in conjunction with a group of volunteers, the Oklahoma Archaeological Survey excavated and recorded the partially articulated skeletal remains of a wooly mammoth in northwestern Oklahoma City. Buried some 3 m below the original ground surface, the bonebed was exposed by heavy machinery during development of a residential subdivision. Extensive soil profile studies were undertaken both within the bonebed and immediately west of the bonebed and indicate an extensive alluvial valley fill of interbedded sands, silts, clays, and quartzite gravels containing bones of *Mammuthus* sp. and unconformably overlain by 3 m of red clay deposits. Bluff Creek is designated as an underfit stream and may relate to the Pleistocene course of the Cimarron River presently 29 km to the north. Radiocarbon dating of skeletal fragments was inconclusive due to Pleistocene ground-water contamination of probable dissolved sulfur.

Introduction

In April 1984, the Oklahoma Archaeological Survey Office (OASO) was notified of the discovery of an "elephant tusk" encountered during grading operations at the Remington residential subdivision site development in northwestern Oklahoma City. The find location was investigated to determine the extent of the skeletal elements, their state of preservation, the depositional environment, and, most importantly, to confirm or deny a possible association with early Paleoindian cultural complexes.

The site was subsequently excavated by OASO staff members and volunteers from the Oklahoma Anthropological Society and others over a period of five days (April 24, 27–30, 1984), exposing partially articulated skeletal elements of *Mammuthus* sp. buried in an ancient braided-stream deposit of late Pleistocene age. Bone fragments of the right ulna were submitted to the Radiocarbon Dating Lab at Washington State University,

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Pullman. No evidence of association with Paleoindian hunters was found; the mammoth apparently died of natural causes and was subsequently buried and preserved by stream-laid sand.

Background

The Allison/Menifee mammoth was discovered by Jeff Allison, construction foreman, during grading operations for the development of the Remington housing addition in far northwest Oklahoma City. The left tusk of the mammoth was struck in its approximate center by the bulldozer blade, at which point Allison hand-excavated a small area around the tusk to determine what he had encountered. Recognizing the find as an elephant tusk, Allison immediately notified the landowners/developers of the project, Jim and Joyce Menifee, and stripping operations were directed away from the find locale. Joyce Menifee subsequently notified the Stovall Museum at the University of Oklahoma, Norman, which in turn relayed the information to the Oklahoma Archaeological Survey Office.

The find area was investigated by Survey staff, and a preliminary test trench was excavated, exposing a nearly complete, intact mammoth tusk greater than 3 m long. The tusk was embedded within an extensive deposit of interbedded sands, silts, clays, and gravels. The test trench was subsequently expanded eastward and encountered a second (opposite) tusk in like orientation less than 1 m away. Faced with the distinct possibility that the tusks were still rooted in the cranium and that additional skeletal elements were likely to be preserved, Survey staff suspended the excavation until a larger crew could be assembled.

Setting

The Allison/Menifee mammoth was encountered at approximately 3.5 m (1087.5′ amsl) below the original ground surface (1099.0′ amsl) on a west-facing valley slope of Bluff Creek in the NW¼ sec. 11, T13N, R4W, Indian Meridian, and within the city limits of Oklahoma City (fig. 1). Specifically, the location is in the southwest corner of Lot 37, Block 5, of Remington Addition.

The topography of the area is one of broad, gently sloping uplands dissected by minor tributary-stream valleys, near the watershed divide between three major drainages: the North Canadian to the south, the Cimarron to the north, and Deep Fork to the east. Bluff Creek, the upper segment of the Bluff Creek/Deer Creek/Cottonwood Creek tributary system of the Cimarron River, flows northward, emptying into the Cimarron at Guthrie, Logan County. The headwaters of Bluff Creek and Walnut Creek, adjacent to the west, extended to within 1.6 km of the North Canadian River and are separated by a divide of less than 12 m of relief in some areas. This becomes most apparent in the vicinity of Wiley Post Airport, northwest of the city of Bethany, where the Bluff Creek Canal

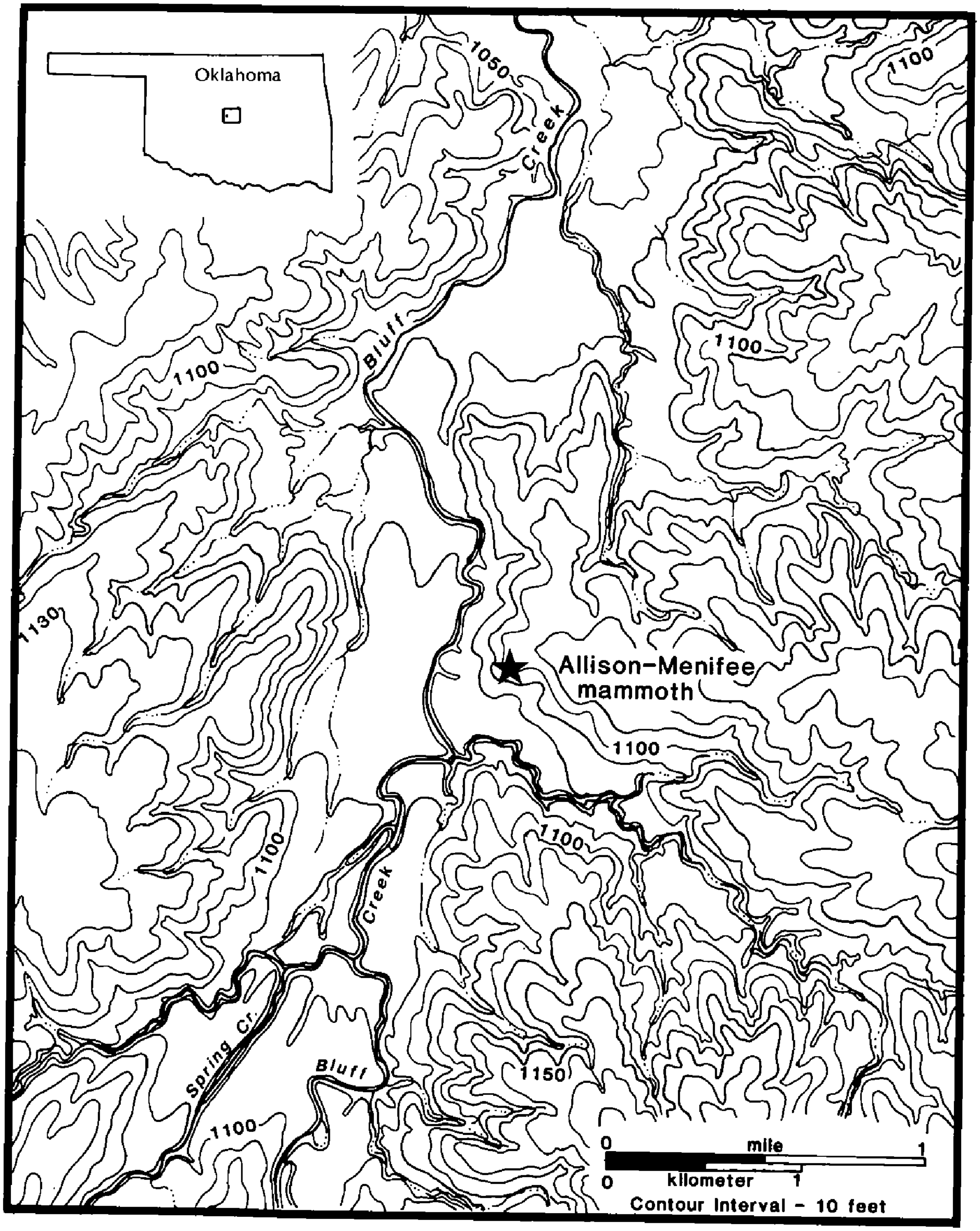

Figure 1. Present topography and drainage pattern in immediate vicinity of mammoth site. Topography from U.S. Geological Survey 7.5-minute-quadrangle series: Britton, Oklahoma (1951; photo revised 1969, 1975).

has been constructed to drain water from Lake Overholser, on the North Canadian River, to Lake Hefner, on Bluff Creek. Stream piracy of the North Canadian by the Cimarron in this area is imminent within geologic time.

In the vicinity of the buried stream deposits, Bluff Creek consists of a small (1–2-m wide), shallow stream entrenched approximately 1 m into an extensive alluvial flood plain of 0.8–1.2 km in width. Six borehole logs of depths of 9–22 m from the NW 150 Street bridge area were provided for study by the Oklahoma Department of Transportation and indicate an extensive valley fill. Borehole 3 records 17 m of interbedded clay, sandy clays, and sands over red shale. The six logs document a deeply buried valley cut through shale of the Salt Plains Formation some distance west of the present creek channel (fig. 2). Bluff Creek is an underfit stream occupying a much older stream valley similar to Deep Fork Creek to the east (Ries, 1954, p. 18). The buried stream deposits may be related to this ancient Bluff Creek valley rather than the Cimarron River valley, presently some 30 km to the north.

Permian stratigraphic units in the area include (ascending) the Wellington Formation, Garber Sandstone, Fairmont Shale, Purcell Sandstone (Kingman Siltstone and Salt Plains Formation), Bison Formation, Cedar Hills Sandstone, and Duncan Sandstone (fig. 3). Pleistocene alluvium overlying the Bison Formation and the Duncan Sandstone generally demarcates the divide between the North Canadian and Cimarron River drainages. Bluff Creek occupies a valley cut into the Fairmont Shale and subsequently buried by alluvium.

Excavation Methodology

After the initial test trench was begun, revealing the stream-buried tusks, excavation was suspended for two days to assemble a larger crew for a more complete excavation. The crew consisted mostly of volunteers from the Oklahoma Anthropological Society Emergency Squad (OASES), whose names are on file at the OASO.

Upon returning to the site locale, the crew extended an additional test trench 0.8 m wide southward from the exposed tusks (fig. 4). The soil matrix was not screened, although some quartzite pebbles and cobbles were collected. All skeletal elements were left in place, and the depth of the excavation was determined by a hard, compact red clay/gravel believed to be the base of the stream channel at the time of deposition and upon which the skeletal elements were resting. Immediately south of the tusks, the mandible was encountered along the eastern edge of the test trench, and at 1.5 m south, the right ulna and articulated forefoot bones were uncovered along the west wall of the trench, extending into the southwest corner (fig. 5).

Excavation was then shifted to the west, leaving a 30-cm balk between the two excavation units for stratigraphic control. This west excavation block was extended 1.5 m west and corresponded in width to the east

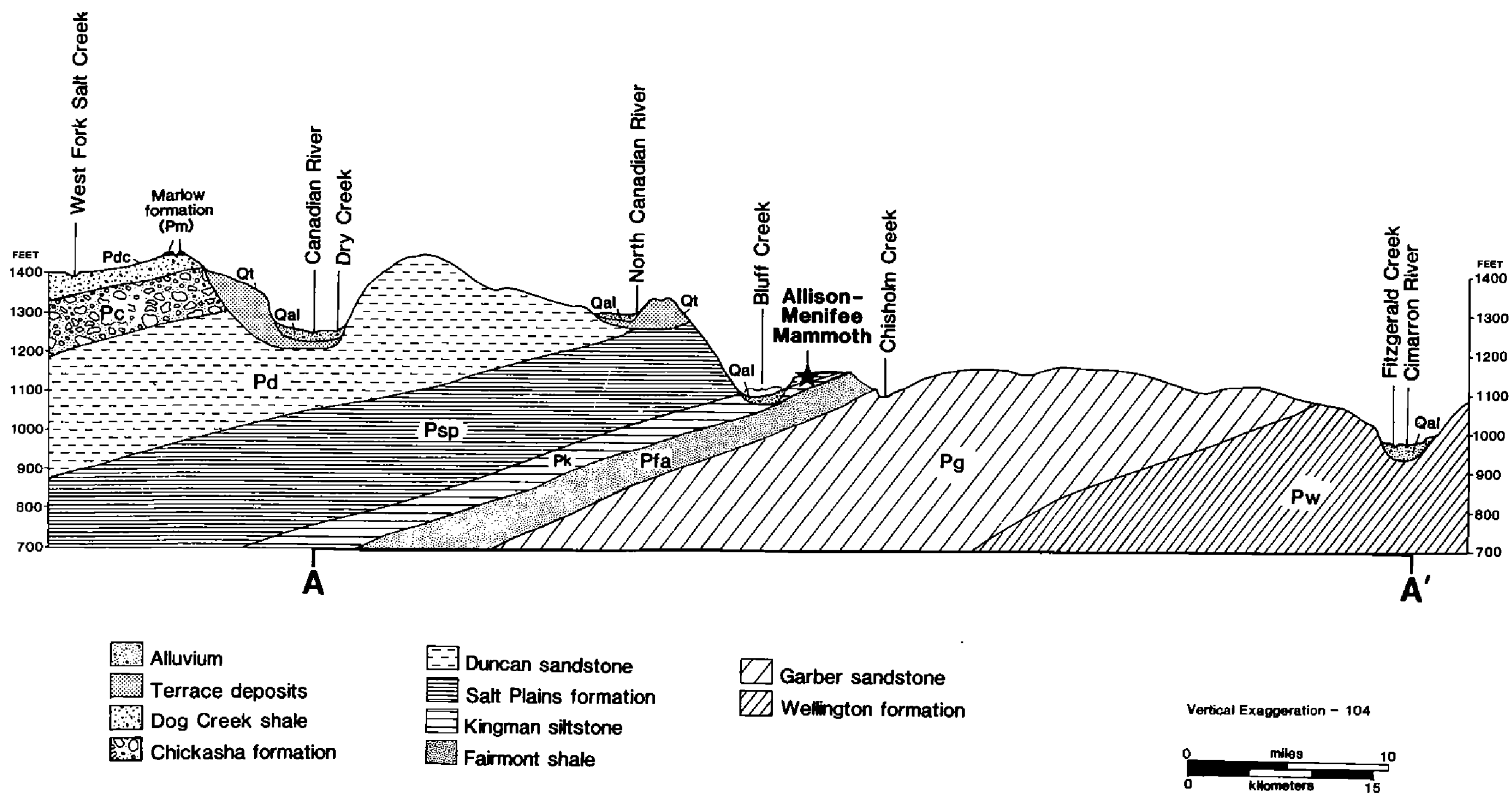

Figure 2. Geologic cross section showing relationships of major stream valleys to mammoth site. Bedrock is Permian. See figure 3 for location of cross section A–A′.

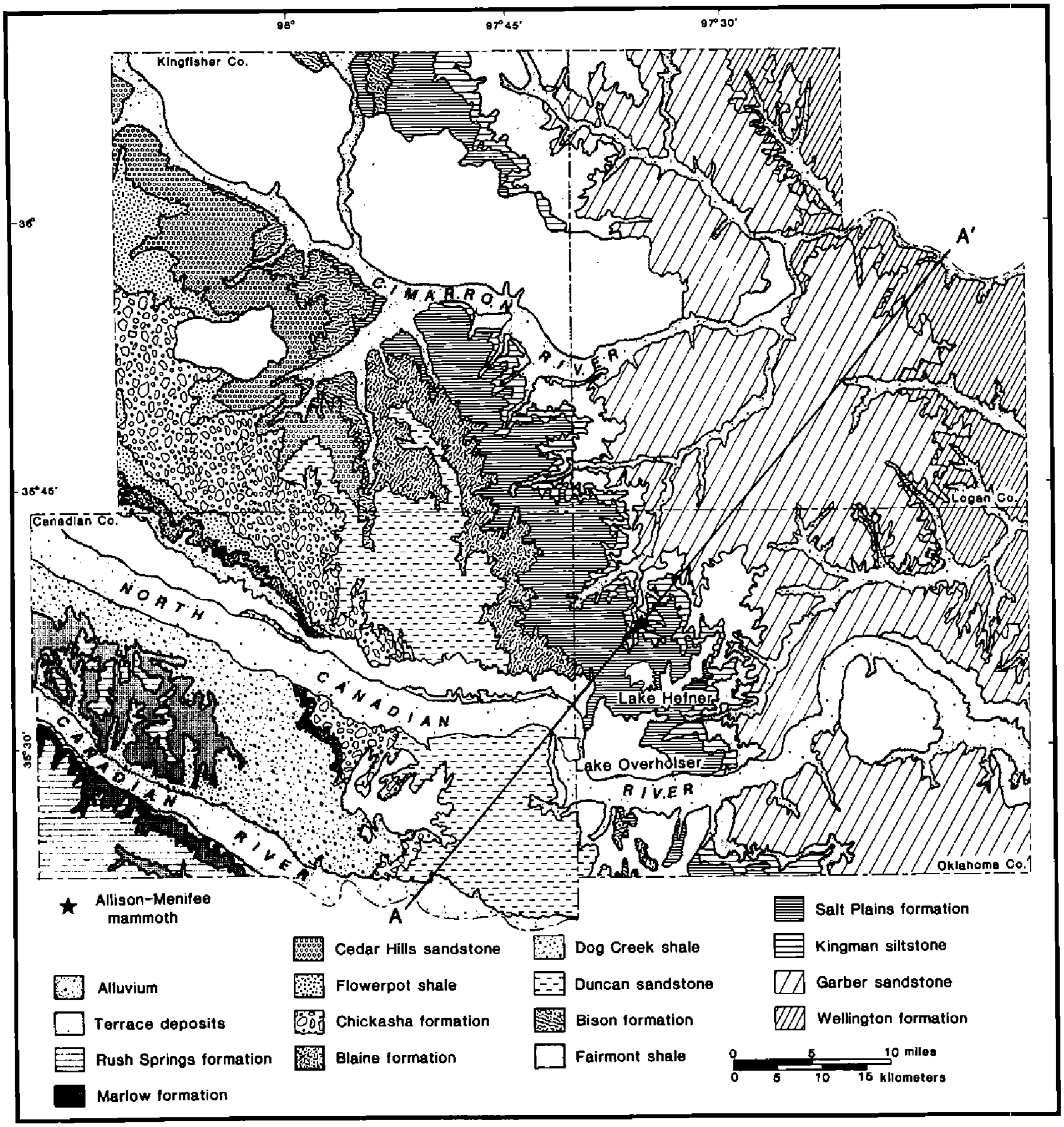

Figure 3. Map of a part of central Oklahoma showing areal geology and present major stream patterns (from Bingham and Moore, 1975). Cross section *A–A'* is shown in figure 2.

test trench. In the northwest corner of this unit, the left scapula, the left humerus, and the proximal one-third of the left ulna were uncovered in association and were resting on the red clay/gravel mentioned above. Immediately above and to the right of this bone assemblage, the right ascending ramus of the mandible was encountered while shaving back the control block for profiling (fig. 6).

Stratigraphic Profiles

One and one-half days of the five-day excavation were spent recording two stratigraphic soil profiles of the complex stream deposits, both within and immediately northwest of the bone bed. Profile 1 details the depositional sequence of a 2.5-m-long north/south section within the bone bed and the relative position of the left scapula, left humerus, and right ascending ramus and condyle (fig. 7). The height of this profile varies from 30 to 74 cm, owing to the slope of the stripped ground surface as well as the uneven nature of the stream-channel bottom. Profile 2 consists of an 11-m section exposed in a road cut 10–15 m west to northwest of Profile 1 (figs. 8, 9). This profile varies in height from 64 to 72 cm.

Profile 1

Unit a Red clay with numerous bone fragments. (This represents the decomposed cranium and rami).
Unit b Red clay.
Unit c Red clayey silt, grading into red sandy clay with white sand laminae.
Unit d White sand with clay balls at base.
Unit e White sand with red silty clay laminae. Some clay balls in center of unit.
Unit f Alternating red sandy silt and white sand with clay balls and quartzite gravels at base.
Unit g Alternating white sand and red sandy silt.
Unit h Red clay.
Unit i Alternating white sand and red sandy silt.
Unit j Red sand.
Unit k Hard, compact red clay/gravel. This represents the base of the stream channel and the surface upon which the bones were resting.

Profile 2

Unit a Red silty to clayey sand with red silt to white sand laminae. Sandstone rocks to 4 cm at base.
Unit b Red sandy to silty clay containing isolated white sand laminae from 0 to 0.3 m; clay balls to 9 cm and sandstone rocks to 3 cm within unit. This represents a low- to high-velocity stream environment.
Unit c Thin to thick discontinuous red clay lenses containing sandstone rocks to 12 cm; interfingers with unit d below.
Unit d Slightly to moderately compact white sand, grading locally into red silty clay; contains clay balls to 3 cm and sandstone

Figure 4. Initial excavation of tusks, showing test trench extending to south. Bluff Creek is in tree line at extreme top center.

rocks to 10 cm at base; very wavy boundary at 4.9, 6.4, and 9.5 m. Grades into unit f below at 10.5 m. This represents an alternating high- to low-velocity stream environment.

Unit e Thin, discontinuous red clay lenses 2.5 to 3.2 and 6.1 to 8 m, not exceeding 3 cm in thickness in any area. This represents a low-velocity stream environment.

Unit f Slightly to moderately compact red sandy to clayey silt containing white sand laminae locally; rounded sandstone rocks to 8 cm at top of unit at 2.0 to 2.6 m. This represents a low- to medium-velocity stream environment.

Figure 5. Complete right ulna/radius *in situ* with forefoot bones in articulation, southwest corner of west test trench.

Unit g Thin lens of red clay 2.4 to 5.3 m, reaching maximum thickness at 4.0 m. This represents a low-velocity stream environment.

Unit h Very loose, well-sorted white sand with individual depositional episodes well defined; contains dark mineral staining/deposition (manganese?) both at the bases (3.5 to 3.8 m and 4.2 to 5.3 m) and at the tops (9.5 to 10.45 m) of bedding units. Individual well-preserved channel remnant at 3.8 to 5.3 m measures 1.5 m wide. Red silt laminae locally present but not abundant; grades into coarse sand and clay balls to 4 mm at 8 to 11 m, similar to individual units in unit j below. This represents a medium-velocity stream environment with main channel to the south.

Unit i Loose to slightly compact red silt, locally grading into red silty clay at 3.5 to 4 m, containing horizontal white sand laminae locally; grades into predominantly white sand at 7 m with scattered horizontal red silt laminae; contains rounded to subrounded clay balls to 5 mm in basal one-half to two-thirds of unit at 9 to 11 m. This unit represents a transitional, medium- to high-velocity stream environment from north to south across the profile.

Unit j Very loose, mostly white sand laminae, finely sorted, well-rounded grains to 3 mm; contains faceted to well-rounded quartzite pebbles of 16 to 52 mm diameter; many round clay balls to 40 mm; several

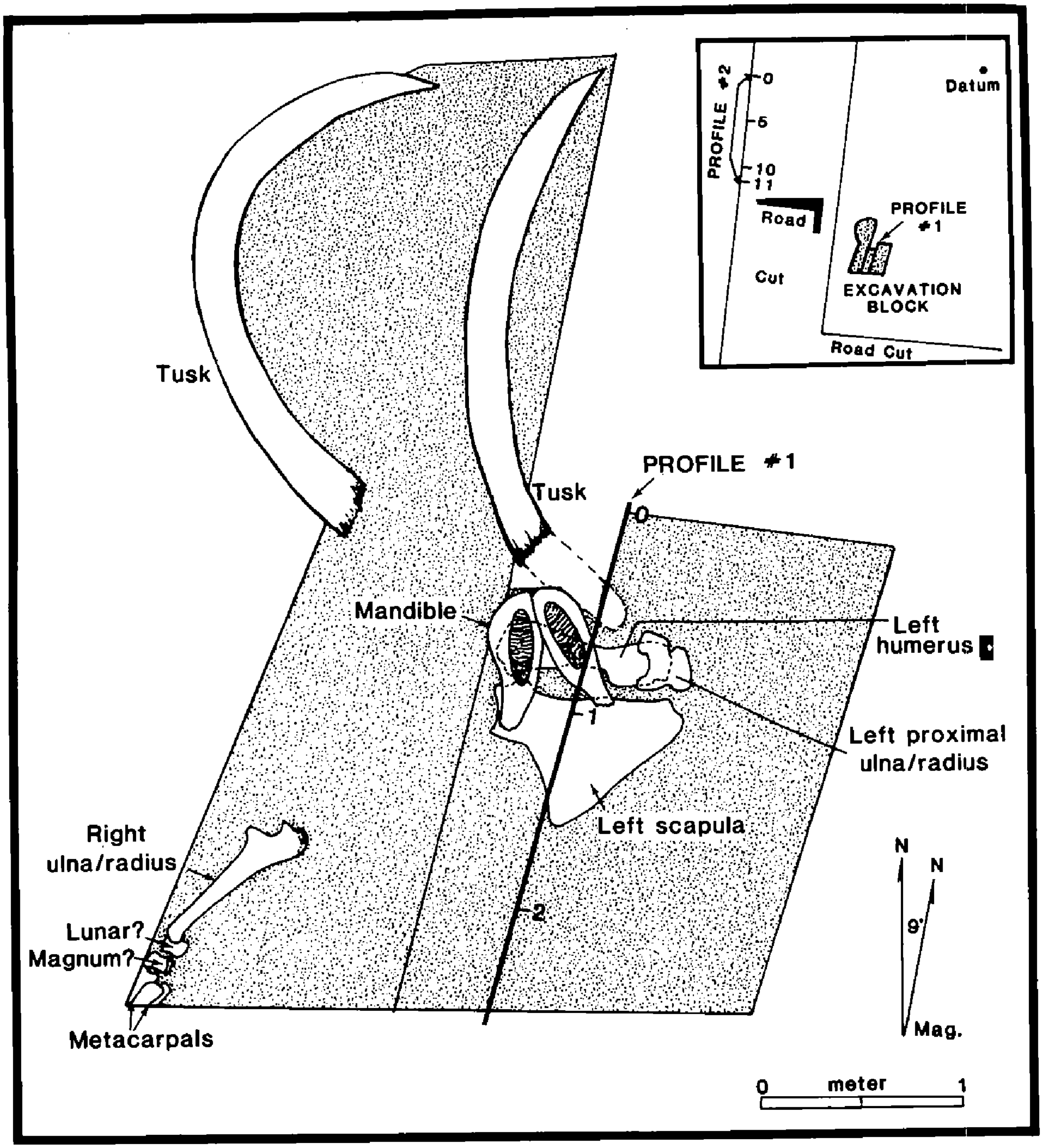

Figure 6. Excavation blocks showing relationships of skeletal elements and profile locations.

different bedding episodes apparent, ranging from horizontal to 30°, locally grading into red silt or alternating red silt/white sand. This represents a shifting, high to medium stream-velocity environment.

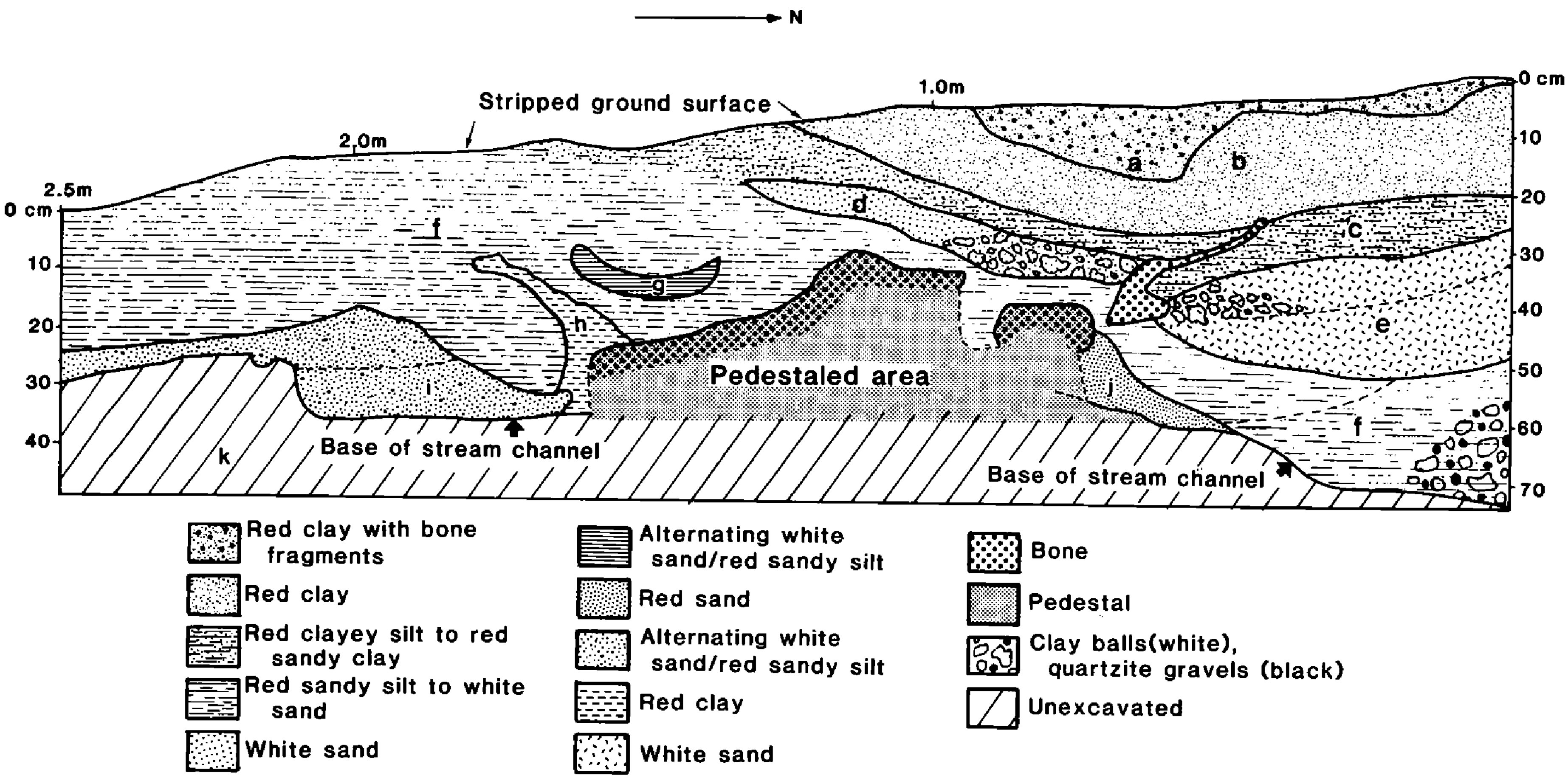

Figure 7. Profile 1, pedestaled bone elements. See text for descriptions of letter designations.

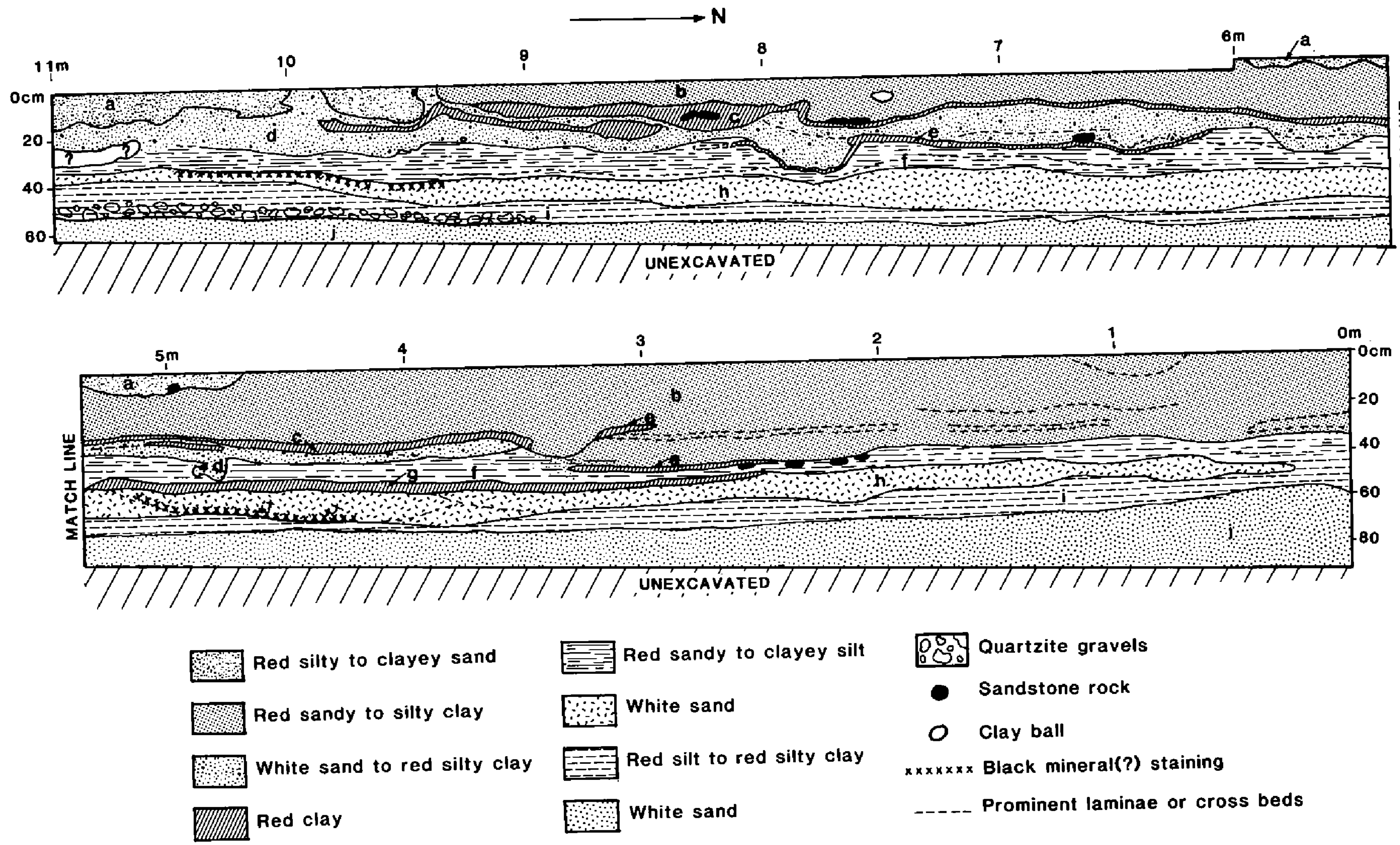

Figure 8. Profile 2, road cut northwest of excavation blocks. See text for descriptions of letter designations.

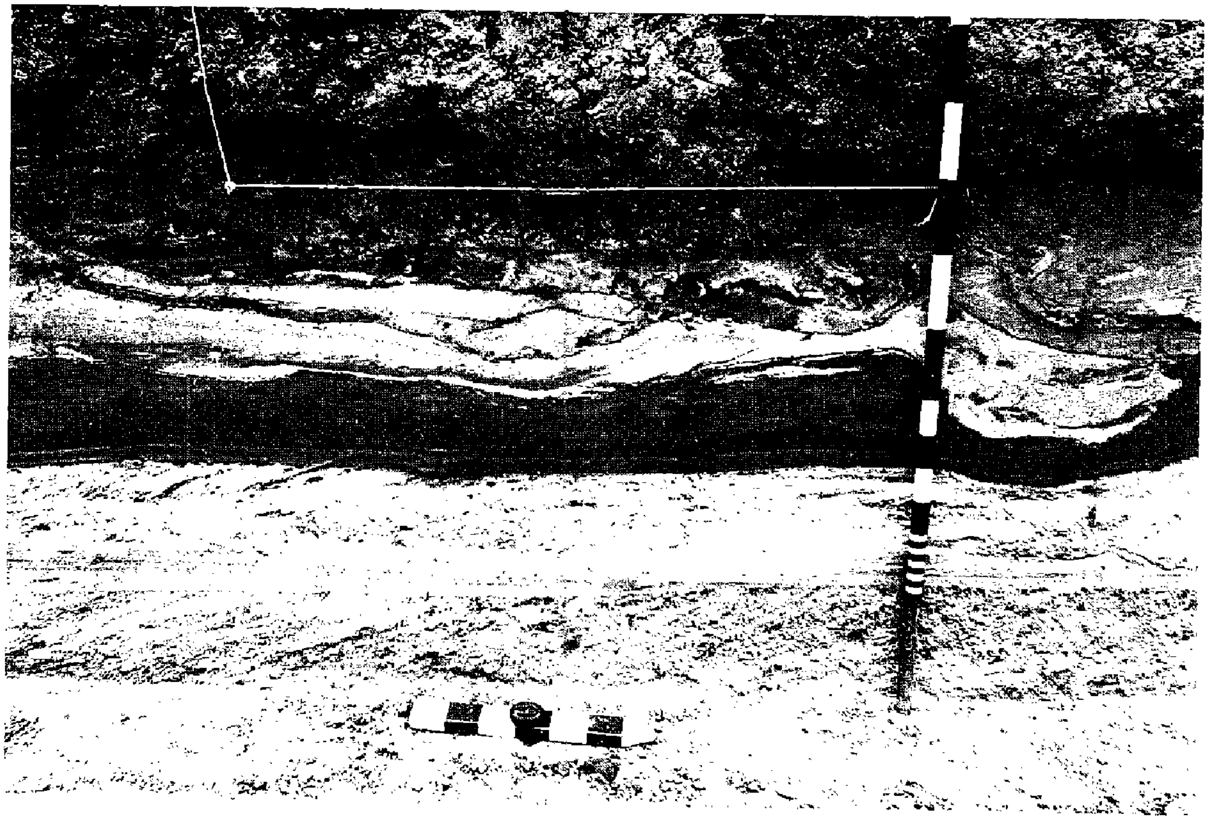

Figure 9. Part of Profile 2. String line represents 1-m section. Compare with figure 8 at 8 to 9 m.

Systematic Discussion

Class MAMMALIA

Order PROBOSCIDEA

Family ELEPHANTIDAE

Mammuthus sp. Burnett, 1830

Mammoth

Abundance.—A single individual, in partial articulation. Complete right ulna with articulated forefoot bones, proximal one-third of left ulna, complete left humerus, complete left scapula, mostly complete mandible, except with eroded left ramus and containing left and right molars in occlusion with upper molars (cranium decomposed *in situ*); both tusks complete, except eroded in region of alveoli. In addition, a left femur head was recovered about 300 m downslope in an area of recently dumped soil and was most likely removed from the road cut immediately south of the main bone deposit.

Habitat.—*Mammuthus* is common in middle and late Pleistocene deposits throughout North America and exhibits a wide range of habitat preferences. In the southwestern United States, *Mammuthus* has been associated with other grazers, and in the eastern United States with browsers including *Mammut* (Saunders, 1977, p. 36). Approximately 2 kg of red clay was recovered from underneath the humerus and submitted to Dr. R. L. Wilson's palynology lab at the Stovall Museum at the University of Oklahoma for recovery of pollen data to aid in the environmental reconstruction of the site. The clay sample, however, was sterile (R. L. Wilson, personal conversation).

Discussion.—The Allison/Menifee mammonth bone bed represents the partially articulated remains of a single mammoth in a deposit of crossbedded stream-laid sands, silts, clays, and gravels. The skeletal elements were recovered from units a–i (Profile 1), which represent several partial fining-upward cycles (Richards, 1982, p. 211) indicative of valley aggradation. All of the bone elements were resting on, or slightly above, unit k, which represents a former stream-channel floor, probably dry at the time of the animal's death. One exception is that of the mandible, which was "stacked" on top of the humerus and scapula, probably as a result of streamflow at the time of burial. Units c–j were deposited rapidly, perhaps within several hours. The distal two-thirds of the left ulna and much of the cranium were not buried at this time, however, as these elements extended into unit b, which marks the boundary between alluvial and probable aeolian deposits.

Mammoth remains have been recovered from throughout Oklahoma. Lintz (1980, table 1) lists 50 localities of finds ranging from a single molar tooth to mostly complete skeletons, while a more recent article by Northcutt (1984) lists 58 mammoth/mastodon sites from southwestern Oklahoma alone. Radiocarbon age determinations range from a pre-35,000-Y.B.P. date on an isolated humerus from Caddo County to 11,045 ± 647 for the Domebo Mammoth, a Paleoindian kill site containing stone spear points of the Clovis style.

Summary and Conclusions

In April 1984 the Oklahoma Archaeological Survey engaged in a five-day salvage excavation of partially articulated skeletal elements of *Mammuthus* sp. in far northwest Oklahoma City. The mammoth had apparently died of natural causes within a braided stream channel and was subsequently buried by fluvial deposits. No evidence of human or other animal predation was observed. Articulated skeletal sections consisted of the right ulna and forefoot bones and the left ulna/humerus/scapula combination. Also present were the mandibles, still joined at the symphysis and "perched" atop the scapula. Left and right upper molars were in occlusion with lower molars, indicating that the skull had decomposed *in situ*. Both tusks were in an anatomically correct position with respect to the mandible, further indicating the former presence of the cranium. Both tusks were eroded at the alveoli.

Although the skeletal elements were intact at the time of excavation, numerous cracks were present, indicating overburden pressure, and internal preservation was poor. As time was not available for proper jacketing and collecting procedures to be employed, some elements were simply loaded into the truck and readily fragmented. Recovered items consist of the right ulna (completely fragmented when moved and much of sheath used for carbon dating), several of the forefoot bones (fair preservation), the teeth (which readily fragmented), and the proximal left ulna (partially mineralized, good preservation). The remainder of the elements were left in place and were subsequently graded away by construction machinery.

Radiocarbon dating of right-ulna collagen at Washington State University was inconclusive, owing to unknown contamination; the results suggest a pre-30,000-Y.B.P. date. Additional bone samples have been supplied to the WSU laboratory for further analysis and will be reported on when available.

The buried stream deposits are on an upland hillslope overlooking Bluff Creek valley, an upper tributary of the Cimarron River. The stream channel lies 33 m below the present North Canadian River, 46 m above the Cimarron River, and 21 m above the present Bluff Creek channel. Exposed channel fill observed on aerial photographs indicates a general north–south orientation to the Pleistocene deposits (fig. 10). The channel width on an east–west line at the bone bed was paced at 101 m where water-line trenches have exposed depths of interbedded sands of 2 + m. Paleoflow is believed to have been from south to north.

Core results from boreholes within the valley fill half a mile north of the bone bed indicate a deeply buried valley cut through the underlying Salt Plains Formation. Within 100 m the shale bedrock dips from 4 to 17 m below the surface and is covered by several sand to sandy-clay depositional sequences. This grades into clay in the upper few meters of the more recent valley fill. The underfit Bluff Creek may occupy a former Pleistocene stream course that no longer exists within the present drainage pattern, or perhaps it represents the northward remnant of a former meander loop of the Cimarron River. Clearly, additional study of Bluff Creek valley and its extensive sediments is necessary in order to interpret the Pleistocene history of this part of central Oklahoma.

Acknowledgments

The following persons are thanked for their assistance during the excavation and during preparation of this report: Jeff Allison, Jim and

Figure 10. Aerial photograph of mammoth site. White areas are exposed braided-stream sands. Photo courtesy of Ace Aerial Photography, Oklahoma City.

Joyce Menifee, Marshall Gettys, Claude Long, Jan Mullins, Don Wyckoff, Merle Hunsaker, Dick Wilson, Mary Goodman, Patricia Hirth, Carlos Devilla, and Roger Saunders.

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WATER-LEVEL CHANGES IN THE OGALLALA AQUIFER NORTHWESTERN OKLAHOMA

John S. Havens[1]

The Ogallala aquifer, that part of the High Plains aquifer in Oklahoma, is part of a regional aquifer system that underlies parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming (fig. 1). In 1978 the U.S. Geological Survey began a 5-year study of the High Plains regional aquifer system to provide hydrologic information for evaluation of the effects of long-term development of the aquifer and to develop a capability for predicting aquifer response to various ground-water-management alternatives (Weeks, 1978).

The Ogallala aquifer in the Oklahoma Panhandle includes the Tertiary Ogallala Formation and the hydraulically connected Quaternary alluvium and terrace deposits. The Ogallala aquifer is a water-table aquifer in which water moves generally to the east-southeast. Before the beginning of extensive irrigation in the 1960's, the aquifer virtually was in dynamic equilibrium. Recharge was from precipitation and was balanced by natural discharge from the aquifer. Natural discharge appeared as baseflow in streams leaving the area or was lost through evapotranspiration.

About 1,600 water-level measurements were used in compiling a predevelopment (1940) water-table map (Havens, 1982c). About 700 water-level measurements made by the Oklahoma Water Resources Board (Havens, 1982b) were used in constructing a 1980 water-table map. Based on differences between the predevelopment and 1980 water levels, a computer-generated map of water-level changes in the Ogallala aquifer from predevelopment (1940) to 1980 was drawn (fig. 2) for the Oklahoma Panhandle, consisting of Cimarron, Texas, and Beaver Counties (Havens, 1983). Calculated water levels for the year 2020 were obtained from Havens and Christenson (1984), and, using the same methods, a map showing water-level changes from predevelopment to 2020 was prepared (fig. 3).

Accurate records of irrigation pumpage from the Ogallala are not available. As an alternative method of estimating irrigation pumpage, published records of crop distribution were used, and a consumptive use was assigned to each principal irrigated crop. Consumptive use and irrigated acreage were then used to estimate an irrigation demand. Irrigation demand is the quantity of water that must be pumped to irrigate

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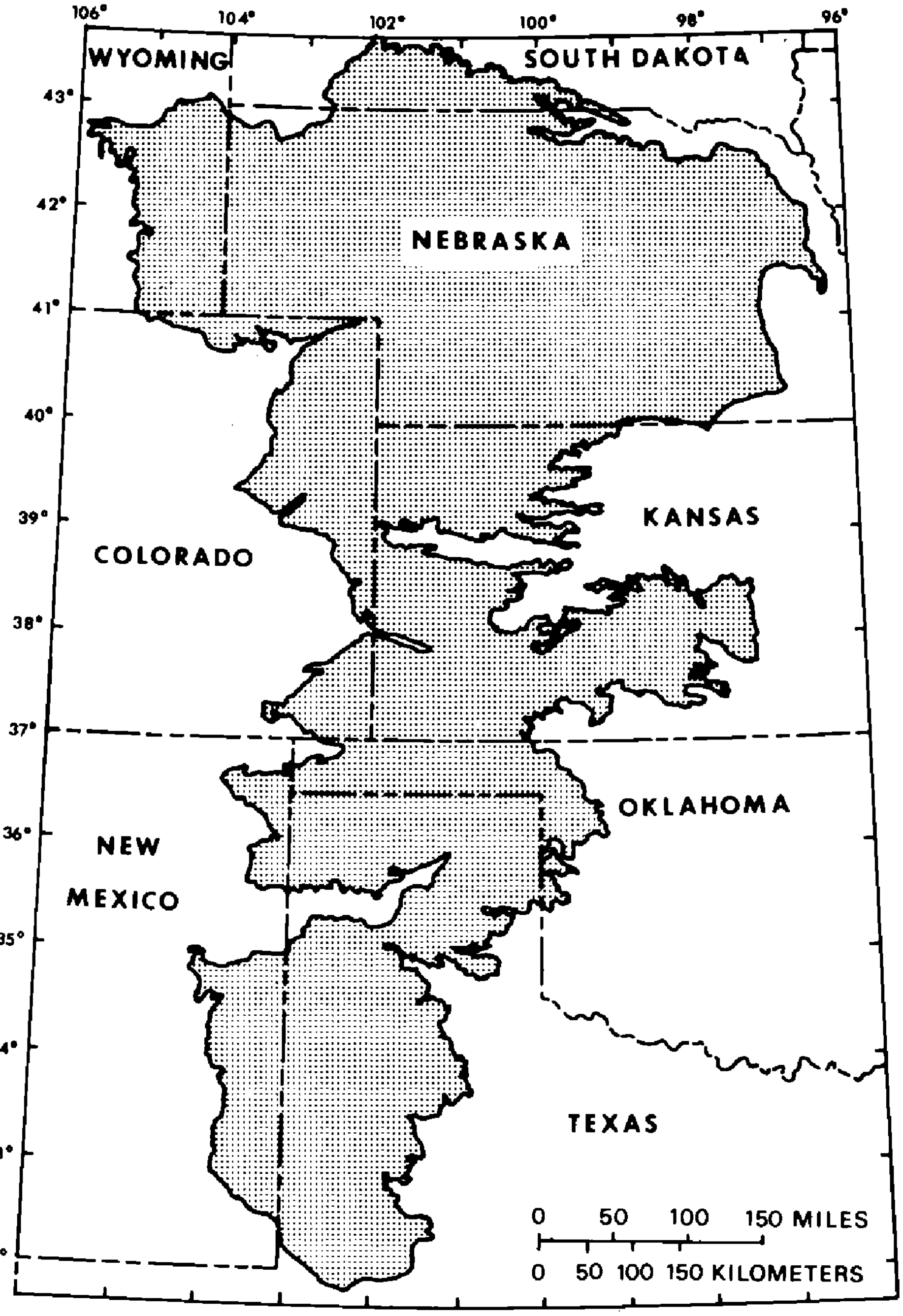
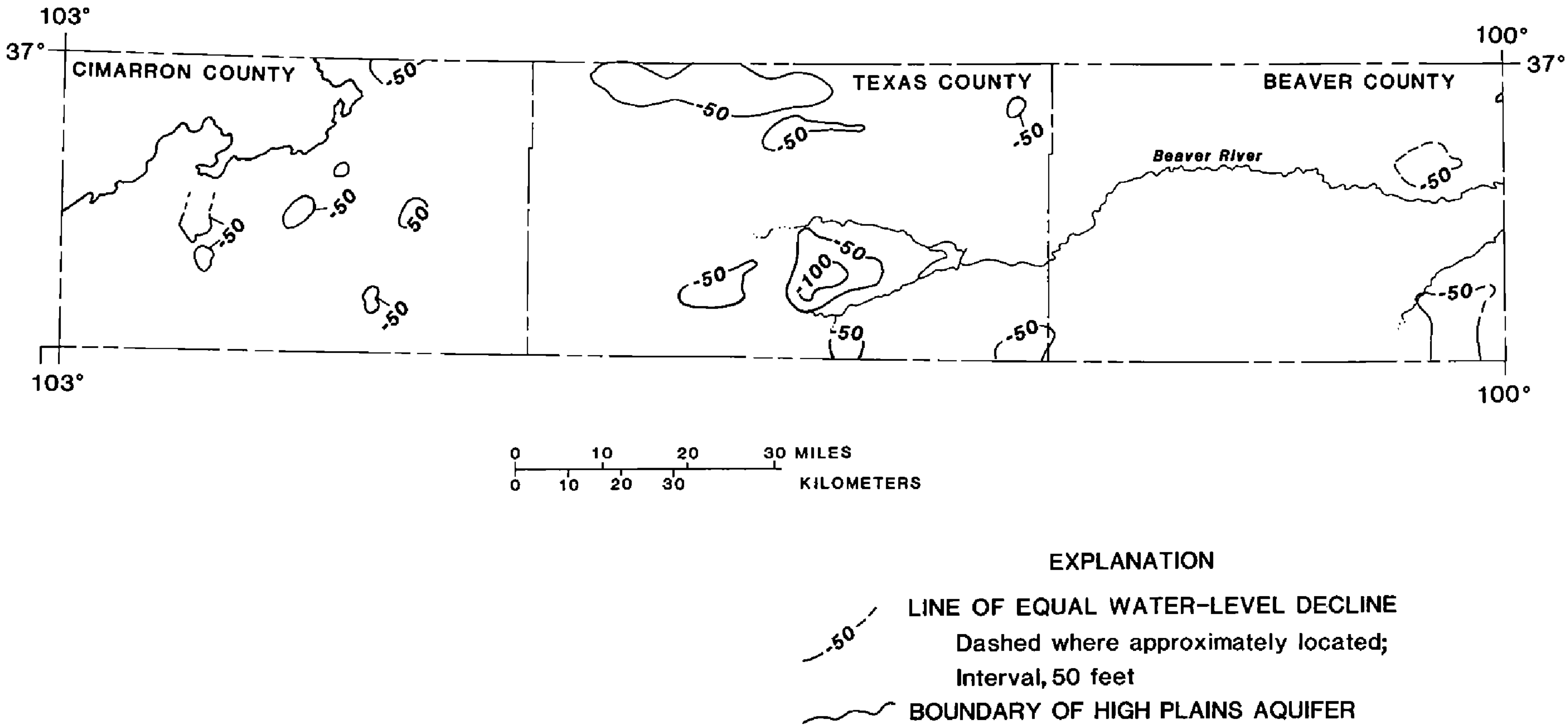


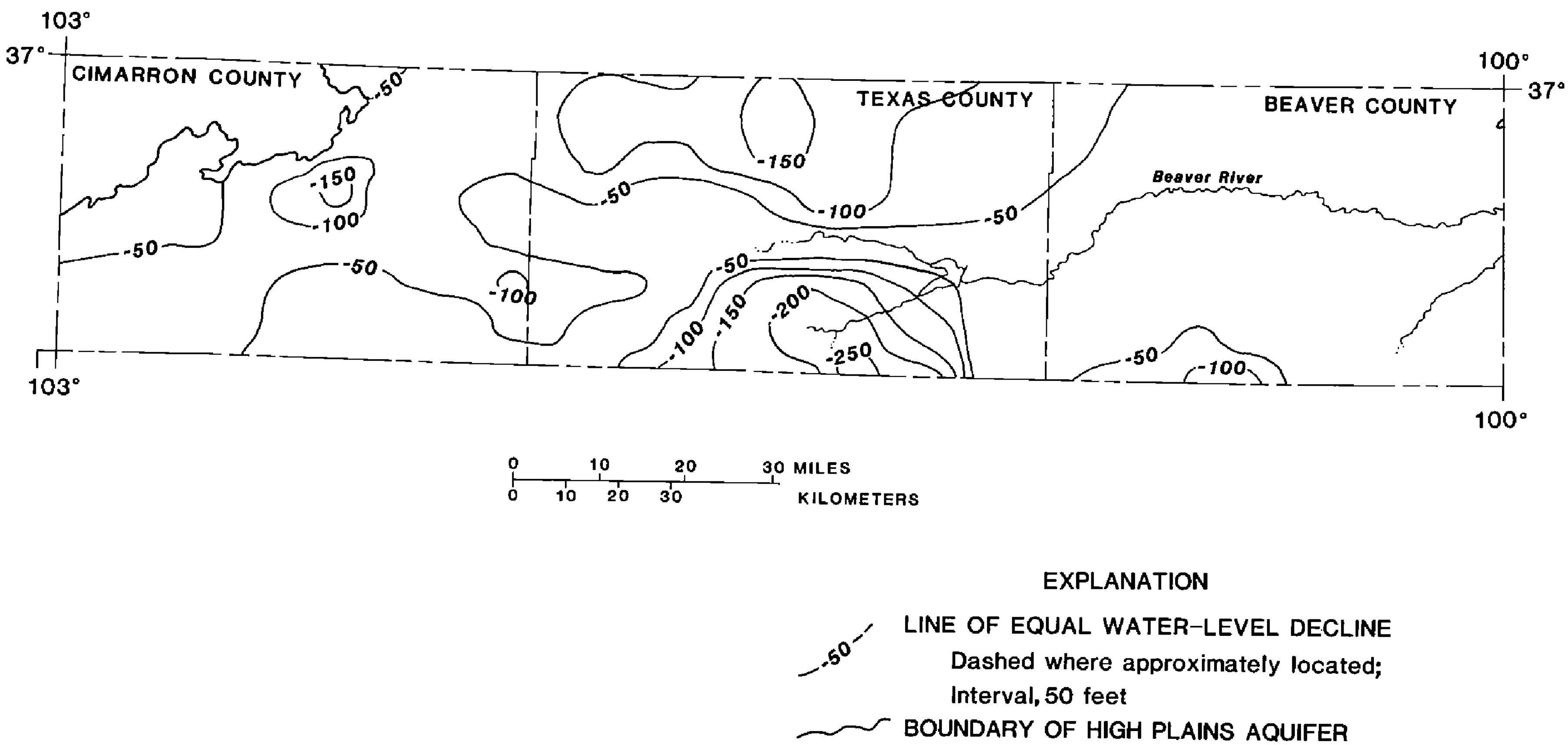
Figure 1. Location of High Plains aquifer (shaded).

a crop, taking into account the quantity of water available to the crop from precipitation (Heimes and Luckey, 1982). Pumpage was taken as a percentage of the total irrigation demand. Discharge from the aquifer to streams was estimated as about 118 ft^3 per second during 1980.



Hydrology modified from Havens, 1983

Figure 2. Historical water-level changes in High Plains aquifer from predevelopment to 1980.



Hydrology by J.S. Havens, 1983

Figure 3. Simulated water-level changes in High Plains aquifer from predevelopment to 2020.

A finite-difference, ground-water-flow model (Trescott and others, 1976) was used to simulate water-level changes in the Ogallala aquifer (Havens and Christenson, 1984). The model was calibrated so that the mean difference between predevelopment modeled and measured water levels was −0.044 ft. Recharge for the predevelopment simulation was adjusted so that 1980 base flow was 118 ft^3 per second.

After the calibration procedure, the model was used as a predictive tool to estimate the changes in water levels and volume of water in storage between predevelopment and 2020 (fig. 3). The 1980 pumping rates were used to predict the volume of water in storage during 2020. The calculated volume of water in storage in the aquifer during 1940 (predevelopment) was 135.2 million acre-feet; during 1980, it was 121.9 million acre-feet; and during 2020, it will be 96.2 million acre-feet. Based on the calculated volumes of water in storage, the volume of water remaining in storage during 1980 was 90% of the water available during 1940, and the 2020 volume will be 71% of the water available during 1940 (Havens and Christenson, 1984).

The Ogallala aquifer in Oklahoma will continue to be an important source of water beyond 2000, even at present rates of pumpage. The water table will continue to decline, however, and streamflow may diminish, or even cease, in areas where the water table is substantially lowered.

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WELL PLANNED TO MONITOR WATER

Final plans are under consideration for construction of a monitoring well by ACOG/GWA in an area of Oklahoma City containing numerous old and new oil and gas wells. The monitoring well is designed to help evaluate the effects of oil and gas activities on the Garber–Wellington Aquifer and provide long-term monitoring of any potential adverse effects.

The plans call for construction of a deep, multiple-cased well to be installed in a playground near S.E. 15th Street and Byers Ave. An easement is currently being reviewed between ACOG/GWA and Oklahoma City with the final site to be mutually agreed upon by all parties.

The well is to be installed utilizing a reverse circulation drilling method only recently developed by the ground-water exploration industry. Water samples will be collected and analyzed at each major sandstone lens and then resampled after well development is completed.

Initial efforts will concentrate on determining what impacts, if any, the large number of oil and gas wells have had on ground water in the area, according to Water Resources Division Director Greg Wallace. The well is scheduled to be constructed this fall with long-term monitoring over the next several years.

The site of the well was chosen based on an assessment performed by the National Center for Groundwater Research (NCGWR) which ranked this area as the top four square miles in central Oklahoma most likely to be contaminated from the proliferation of activity in the area. The monitoring-well site is centrally located within the area and will be utilized as a field check of the assessment performed by NCGWR and to help predict potential future problems.

Taken from *Garber–Wellington Gazette*, August 1985.

WILLIAM D. ROSE LEAVES OGS

People come and people go on the staff of the Oklahoma Geological Survey. Most commonly, people come and stay on the staff for long terms, and some of the most outstanding practitioners in the fields of the earth sciences have done just that. (See OGS SP83-2, *A History of the Oklahoma Geological Survey*.)

In May 1970, one of these outstanding professionals, William Dake Rose, came to serve as geologist/editor for OGS. He stayed for 15 years, resigning this past summer to become manager of publications for the National-Science-Foundation-supported Ocean Drilling Program, the successor to DSDP (the Deep Sea Drilling Project), at Texas A&M University at College Station, Texas.

Bill Rose came to our survey from the Kentucky Geological Survey, where he had served for four years as editor and head of the publications section.

Born and educated in Nashville, Tennessee, (A.B. and M.S. in geology, Vanderbilt University) Bill began his career in Nashville — as a student geologist with the Tennessee Division of Geology. His education was interrupted, or augmented (?), by two terms of duty with the United States Army, which he served as a bandsman, part of the time in Germany. He is a fine musician, a flautist, very knowledgeable and appreciative of good music.

Following receipt of his master's from Vanderbilt, Bill went to work for Gulf Oil as a petroleum geologist in Midland, Texas, leaving there after three years to serve as a petroleum and subsurface geologist for the Kentucky Geological Survey, and thence into editing.

He became one of the top editors in the field of geological publication, was a charter member of the Association of Earth Science Editors and was instrumental in developing the growth and effectiveness of the Association, which he served as secretary-treasurer, vice-president, president, and as the Association's representative to the American Geological Institute. He has also been a perennial member of AGI's Publications Committee.

He has been very active in the American Institute of Professional Geologists (AIPG), serving as vice-president and president of the Oklahoma Section and on committees for the national organization. He has held committee memberships in the Association of Petroleum Geologists and was author of AAPG's *News-Release Handbook*. He has numerous other publications to his credit, either as author, editor, or compiler, for the Kentucky Survey, OGS, and AAPG.

Facts. Professional history.

But you can't put Bill Rose on paper alone.

He is a fine gentleman, southern style, courteous to all, never heard to raise his voice in anger and only occasionally emitting a scarcely audible low-key response to frustrations. He is a fine friend and supporter to many; polite, helpful, firm with his co-workers; loving and loyal to his family; an avid and dedicated church worker; generous to all; a devout stickler; and in his work a perfectionist who had set new standards toward excellence in OGS publications.

We are most grateful that Bill Rose came to the Oklahoma Geological Survey and that he stayed as long as he did. His post will be filled, and we hope soon, but it will be impossible to fill his place.

We will miss William Dake Rose and Virginia very much, and we wish them all things good in their new life.

Elizabeth A. Ham

JOHNSON ATTENDS MEETING IN TURKEY

Kenneth S. Johnson, associate director and research geologist of the Oklahoma Geological Survey, presented a report on one of the State's major ground-water aquifers at a recent international conference held in Ankara, Turkey.

Johnson offered data on his studies of the Blaine aquifer, which is the source for abundant irrigation water used by farmers and ranchers in Harmon, Jackson, and Greer Counties of southwestern Oklahoma. The title of his paper was "Hydrogeology and Recharge of a Gypsum-Dolomite Karst Aquifer in Southwestern Oklahoma, U.S.A."

The theme of the conference was "Water Resources in Karst Regions," with "karst" regions being those areas where soluble rocks, such as limestone, dolomite, or gypsum, have been partly dissolved to create caves, sinkholes, disappearing streams, and underground cavern systems.

Major limestone and dolomite aquifers of Oklahoma with karst features include the Boone and Roubidoux aquifers in the northeast and the Arbuckle aquifer in the southwest and south-central parts of the State.

The Blaine aquifer, on the other hand, is a sequence of gypsum beds with extensively developed karst features in Harmon, Jackson, and Greer Counties in the far southwest.

Irrigation water is pumped from the Blaine at rates of 300 to 2,500 gallons per minute and is critical to agricultural development in a region noted for its wheat, cotton, sorghum, and cattle raising.

Although local citizens have been able to partly recharge the Blaine aquifer by diverting streams into sinkholes and by drilling water-injection wells, Johnson's study of the geohydrology of the Blaine will help improve the program of exploration, production, and recharge of the Blaine aquifer.

SYMPOSIA SET FOR SME–AIME MEETING

The Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (SME–AIME) has announced four symposia to be held as part of the annual meeting scheduled for March 2–6, 1986, at the Hilton Hotel in New Orleans, Louisiana.

The "Arbiter Symposium on Advances in Mineral Processing" will honor mineral-processing educator Nathaniel Arbiter on his 75th birthday. About 30 papers are scheduled for presentation at the three-day, six-session symposium. Topics include comminution and gravity separation, flotation theory, flotation process, hydrometallurgical and magnetic techniques, design and scale-up—machines and processes, and integration of theory and practice.

A two-day symposium is scheduled to review "Application of Rock Characterization Techniques in Mine Design." About 20 papers will be presented at the six-session symposium. Topics include mine design, ground control in metal mining, rock breakage, general principles, case studies, and ground control in coal mining.

A three-session symposium on "Transportation Handling, Innovations, and Policy Implications" will cover new developments in materials handling, new frontiers in transportation, and policies and implications of the transshipment of large volumes of material, particularly coal and industrial minerals.

A four-session symposium on "Engineering Health and Safety in Coal Mining" will be an engineering assessment of health and safety program methods and techniques and the implementation of those methods. Topics include human factors, health effects and accident analysis, geomechanics and operational aspects, and environmental facets.

The papers for each symposium (with the exception of the "Transportation Handling, Innovations, and Policy Implications" symposium) will be included in a proceedings volume available at the meeting.

For further information, contact Lori A. Penrod Yocovella, Meetings Dept., Society of Mining Engineers of AIME, Caller No. D., Littleton, CO 80127; telephone (303) 973-9550.

CALL FOR PAPERS: SME–AIME FALL MEETING

The Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (SME–AIME) has issued a call for papers for the fall meeting, to be held September 7–10, 1986, in St. Louis, Missouri.

In the Coal Division, papers may be submitted for presentation at the following sessions: environmental, health and saftey, preparation, research and development, surface mining, underground mining, and utilization.

The Industrial Minerals Division is accepting papers for presentation at sessions on dry crushing and grinding of industrial minerals, economics of industrial minerals for desulfurization, clays, economics of fluorspar, and specialty ceramics.

The sessions in the Mining and Exploration Division include geology—mineralization along the mid-continent drift, hydrology—dewatering of carbonate ores in the Missouri lead belt, application of operations research techniques in mine equipment selection, solution mining for low-cost production, and underground ventilation.

The Mineral Processing Division seeks papers for presentation at sesssions on extractive metallurgy of lead and zinc—pyrometallurgy, hydrometallurgy; gold technology; coal processing; process improvements in pelletizing; concentration—general, concentration related to coal preparation; fundamentals of mineral processing; size reduction of phosphate rock and concentrate; and dry crushing and grinding of industrial minerals.

The Minerals Resource Management Committee solicits papers for sessions on economics of high sulfur coal, desulfurization of coal, inland transportation, economic aspects and marketing of lead and zinc, economics of minor metals, economics of industrial minerals for desulfurization, and economics of fluorspar.

For more information, contact Lori A. Penrod Yacovella, Meetings Dept., Society of Mining Engineers of AIME, Caller No. D, Littleton, CO 80127; telephone (303) 973-9550.

NOTES ON NEW PUBLICATIONS

Future Employment Opportunities in the Geological Sciences

Produced from summaries of presentations at the GSA forum on Future Employment Opportunities in the Geological Sciences held in Reno, Nevada, on November 5, 1984, this booklet is intended to aid persons new to the job market in selecting prospective employers and determining career goals. The booklet discusses employment trends and opportunities in the petroleum and mining industries, federal and local governments, and academia. It also provides tips for successful resumes and interviews and presents some salary figures.

Order from: Geological Society of America, P.O. Box 9140, Boulder, CO 80301. There is no charge for single copies of the booklet.

Surface-Water and Related-Land Resources Development in the United States and Puerto Rico

Compiled by Kerie J. Hitt, this new map shows major water-development projects across the country, including the location, size, and ownership of about 2,800 major multipurpose and flood-control dams and virtually all of the nation's reservoir storage and flood-control capacity. Other features include (1) U.S. Bureau of Reclamation surface-water irrigation projects, (2) watershed-protection projects of the U.S. Soil Conservation Service, (3) federal and non-federal hydroelectric power plants licensed by the Federal Energy Regulatory Commission, (4) U.S. Army Corps of Engineers navigation and flood-damage-reduction projects, and (5) the federal system of wild and scenic rivers. The one-sheet color map measures about 38 × 62 in. and is printed at a scale of 1:3,168,000 (1 in. = about 50 mi).

Order from: U.S. Geological Survey, Western Distribution Branch, Box 25286, Federal Center, Denver, CO 80225. The price is $4.

Finance for the Minerals Industry

Editors C. R. Tinsley, W. D. Eppler, and M. E. Emerson have compiled a basic reference on finance for the minerals industry. The 844-page book covers financial requirements, capital structure, financial evaluation, accounting, taxation, profit and economic rent, impact of mineral-development agreements, risk analysis, information requirements, sources of finance, and case studies of actual mineral projects.

Order from: Society of Mining Engineers of AIME, Dept. PRL85 SME Books, Caller No. D, Littleton, CO 80127. The price is $40 for AIME members, $50 for nonmembers, plus $3.50 for shipping and handling. Colorado residents must add sales tax; Canadian orders must add 25%.

OKLAHOMA ABSTRACTS

GSA, South-Central Section, Annual Meeting Fayetteville, Arkansas, April 14–16, 1985

The following abstracts are reprinted from *Abstracts with Programs, 1985* of the Geological Society of America, v. 17, no. 3. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Statistical Analysis of Morphologic Variables on North and South-Facing Slopes, Glass Mountains, Oklahoma

RICKY A. NUSZ, Department of Geography, Oklahoma State University, Stillwater, OK 74078

A study was conducted to determine if significant differences occur in hillslope morphologic variables between north and south-facing slopes. Data were collected at 5 meter intervals along transects on twenty-eight north and twenty-eight south-facing slopes. Transects were extended from the caprock to the base of the first erosional terrace located at the base of the slope.

Morphologic variables calculated included: 1) slope length, 2) height, 3) curvature index, 4) maximum angle, 5) distance from caprock to maximum slope angle, 6) steepness, 7) percent length above the major break-in-slope, and 8) percent length below the major break-in-slope.

To test for significant differences between these variables as related to aspect, a two sample t-test was performed. Length, height, maximum angle, and steepness were all found to be significantly different at the .05 level of confidence.

Given these results, it would be difficult to determine the degree to which slope aspect controls slope development in this area. In order to determine if other variables independent of aspect control slope development, regression analyses were undertaken. The independent variables chosen were thickness of caprock, lithology of caprock, and distance from caprock to regional base level. The dependent variables length, height, maximum angle, distance to maximum angle, and curvature index were found, for both aspects, to correlate significantly (.05 level) with the independent variables.

These results suggest that other variables, independent of aspect, may be major contributors to slope development in this area. [186]

OKLAHOMA ABSTRACTS is intended to present abstracts of recent unpublished papers relating to the geology of Oklahoma and adjacent areas of interest. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings, that have not yet been published.

Allodapic Conodonts of the Dimple Limestone (Atokan, Pennsylvanian), Marathon Region, Texas

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Conodont faunas from the Dimple Limestone, first described by Ellison and Graves (1941), show pervasive reworking in all sections. Contrary to previous interpretations, the Dimple contains no shelf deposits, rather it represents a transition from channelized proximal submarine fan deposits to distal basinal deposits. This conforms to the model of submarine carbonate deposition presented by Wright and Wilson (1984).

Pennsylvanian conodonts of both Morrowan and Atokan age are abundant in the Dimple. Five conodont species, *Idiognathoides convexus, Declinognathodus noduliferus, D. lateralis, Neognathodus bassleri,* and *N. medadultimus* co-occur. The Dimple Limestone is thought to be Atokan in age, on the basis of the occurrence of *N. medadultimus*. It is correlative with Atoka Formation from the Arbuckle Mountains of Southern Oklahoma, rather than the Wapanucka Formation, which is Morrowan in age (Grayson, 1984).

Reworked pre-Pennsylvanian conodonts are common throughout the Dimple. Large numbers of Upper Devonian and Upper Mississippian conodonts with fewer Ordovician and Lower Mississippian elements occur along with rare Silurian specimens. The excellent preservation of many ramiform and platform elements and the volume of siliceous shale in the most distal sections fit a model of submarine canyon erosion through the carbonate shelf and into underlying shale formations. [188]

Cryptalgal Boundstone Morphologies in the Timbered Hills and Arbuckle Group Limestones of Oklahoma

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With the exception of the basal Reagan Sandstone (orthoquartzite), the late Cambrian–early Ordovician Timbered Hills and Arbuckle Groups are composed primarily of limestone with variable amounts of dolomite. Recent studies have shown that most of these carbonates were deposited under hot, dry climatic conditions in shallow, epicontinental seas. These conditions, coupled with a chemically hostile atmosphere, were conducive to the growth of algal boundstones which comprise a significant percentage of several of the formations.

The morphologies of the boundstone complexes vary considerably which, therefore, required the establishment of a modified descriptive system based on several existing classification schemes in order to facilitate comparative studies throughout the section. The classification

includes four [categories] into which the boundstones are subdivided in a descending hierarchy. The [categories] are: 1) gross cryptalgal structure (e.g., algal mounds); 2) organization of members in the structure (e.g., colonies); 3) external descriptions of members (e.g., digitate); 4) internal texture of members (e.g., stromatolitic).

After the boundstones were appropriately classified, a determination of local paleoenvironments (i.e., the general depth of water in which the boundstones formed) was made. Maximum sea level change, both [spatially] and temporally through most of the 1500 meters of preserved section, appears to have ranged only from the supratidal zone to the upper subtidal zone. Shallow water sedimentary structures and lithologies associated with the boundstones were used to substantiate this conclusion. [188]

The Case Histories of Three Industrial Waste Injection Wells in the Mid-Continent Area

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The injection of liquid industrial waste into selected salaquifers is the safest, most economical, and least environmentally degrading method for handling a wide range of hazardous materials.

With the present tendency toward overregulation the role of the hydrogeological consultant as a liaison between governmental agencies and well operators is becoming increasingly important, as shown in the case studies.

The first case well was required to take the plant effluent and all storm water runoff. A large diameter well, which tested the required capacity, was drilled through the Arbuckle group and excessive minerals in the effluent were precipitated before injection. The log suite of the injection well showed two shallow oil zones. One zone later had several oil wells completed in it, the revenue from which helped offset the cost of the injection system.

The second case well replaced a successful well, operated since 1960. Questions arose about the old well and many others throughout the Mid-Continent area relating to injection pressures, fluid dispersion within the salaquifer, fracturing, and aquicludes. Test data analyzed gave answers to these questions closely approaching geologists' predrilling prognosis.

The third case well is illustrative of the effect of the temperature of the injected fluid upon the hardware and well monitoring system. A relatively high temperature injected fluid caused problems which an untrained observer may have misinterpreted as tubing or casing leaks.

[188]

Crustal Style Controls in Ouachita Fold–Thrust Belt

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The Ouachita belt is, not conclusively, the upper-plate front of a south-dipping subduction, with documented supracrustal transport and imbrications of 150 km and with late-orogenic intracrustal transport of 25 km. Arbuckle stratigraphy and basement-top geometry show that the foreland evolved from a passive margin with 100 km flexural thickness, to a fragmented and end-loaded foredeep, 35 km thick, and to a belt of external massifs detached at 10 km flexural thickness. Rigidities decrease from $1.5.10^{31}$ dyne. cm to 2.10^{28} dyne. cm.

Style zonation is classical; it includes (1) detached open folds, (2) external imbricate thrusts, (3) cleavage fan and polyphase retrocharriage, (4) internal imbricates, (5) undeformed detached belt. It can be interpreted as a wedge deforming to maintain critical taper during changes in depocenter geometry and crustal tectonics.

Zones (1), (2) show blind thrusting and subcritical taper. Zones (2), (4), (5) suggest steady-state thrust progradation. Zone (3) records a major, Desmoinesian or later, reshaping of the wedge, such as by emergence of the northern depocenter and submergence of the southern source terrane.

Zone (3), the Benton–Broken Bow uplift, is coincident neither in orientation nor in timing with the basement highs. Their rise over intra-basement ramps deformed the fans of cleavage and folds, producing open anticlines of cleavage on the south flank of Zone (3) and part of the blind thrusting in Zone (1). [189]

Petrology of Iron–Titanium Oxides of the Glen Mountains Layered Complex, Oklahoma

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The Glen Mountains Layered Complex forms the mafic core of the Wichita Mountains of southwestern Oklahoma. The Fe–Ti oxides are minor components of the interlayered anorthosites, anorthositic gabbros, and troctolites, but their compositions and textures are of considerable interest in that they may control the petrologic evolution and paleomagnetic characteristics of the intrusion, as well as indicate economic potential.

The Fe–Ti oxides are present in four distinct modes: 1) Composite titanomagnetite–ilmenite in which titanomagnetite is characterized by minute (<1 μm in width) trellis-type ilmenite derived by oxyexsolution and, much less commonly, coarser trellis ilmenite. 2) Discrete, generally optically homogeneous ilmenite, and less common titanomagnetite. 3)

Vermicular titanomagnetite–ilmenite symplectically intergrown with orthopyroxene in coronas around olivine. 4) Crystallographically controlled rod-like inclusions obvious in plagioclase and clinopyroxene. Both types 1) and 2) are intercumulus, enclosed in or associated with intercumulus clinopyroxene. Many of the inclusions in plagioclase are magnetite, as indicated by the magnetic character of plagioclase containing inclusions, but microprobe analysis indicates that some inclusions are more Ti-rich than ilmenite. [190]

Lower Mississippian Transgressive–Regressive Carbonate Sequence, Southern Ozark Region

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The Kinderhookian–Osagean (Lower Mississippian) St. Joe and Boone Limestones represent an unconformity bounded transgressive–regressive sequence widely distributed throughout the southern midcontinent. As Mississippian seas transgressed an irregular erosional surface developed on the Chattanooga Shale (Upper Devonian) or older strata, they deposited a thin interval of sandstone, shale or the two together derived from those older beds. Carbonate deposition was initiated as grain-dominated, crinozoan–bryozoan wackestones and packstones, with subordinate grainstones, and is essentially chert-free. These carbonates, referred to the St. Joe Limestone, reflect a ramp across northern Arkansas that experienced condensed sedimentation and red coloration along its conditions reflected by carbonate mudstones and penecontemporaneous chert of the overlying lower Boone Limestone. The upper Boone (Burlington–Keokuk equivalents) represents a regressive sequence that returned St. Joe-type, grain-dominated, lithologies with diagenetic chert replacement to the shelf. The regression terminated in a pronounced regional unconformity overlain by Meramecan or younger strata. [191]

Pennsylvanian Lower Atoka Formation, Ouachita Mountains, Arkansas and Oklahoma: A Stretched-Out Basin-Plain Fan Deposit

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The Pennsylvanian lower Atoka Formation crops out in the Ouachita fold–thrust belt of Arkansas and Oklahoma. It was deposited in an elongate remnant ocean basin with a longitudinal sediment dispersal pattern, westward parallel to the basin axis. Two principal facies associations are recognized that represent deposition in the middle to lower fan transition zone and lower fan regions of a large, sand-rich, deep-sea fan complex. The middle to lower fan transition zone facies

association consists of amalgamated sandstone packets up to 40 m thick, interbedded with relatively thin-bedded intervals. Thickening-upward (uncommon) and thinning-upward (common) cycles (<10 m thick and occasionally arranged symmetrically) are associated with the amalgamated sandstone packets. These cycles are interpreted, respectively, to result from localized progradation of proximal portions of depositional lobes (possibly initiated as large crevasse-splays that subsequently became avenues for new channels), and gradual abandonment of relatively wide and shallow distributary channels. The lower fan facies association consists largely of classic turbidites with some intercalated amalgamated sandstone packets <5 m thick. Thickening-upward and thinning-upward cycles are interpreted, respectively, to result from progradation and progressive abandonment of distal portions of depositional lobes in the lower fan region. These cycles, however, are relatively uncommon and poorly developed, and the lower fan region may have been more aggradational than progradational in character. The lower Atoka depositional system is significantly different from recent submarine fan models. It is characterized by an areally extensive middle to lower fan transition zone, a lower fan region lacking well-defined progradational depositional lobes, and a longitudinal sediment dispersal pattern. It can be described as a stretched-out basin-plain fan complex.
[193]

Applied Surface Gamma-Ray Spectroscopy in the Ouachita Overthrust of Arkansas and Oklahoma

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Surface gamma-ray spectroscopy methods provide an efficient and effective means of stratigraphic correlation and source rock assessment in frontier areas of petroleum exploration as exemplified in the Ouachita Overthrust of Arkansas and Oklahoma. Surface gamma-ray logs are obtained from measured stratigraphic sections with a portable integrating gamma-ray spectrometer. This method enables correlation of surface outcrops to down hole gamma-ray logs.

Part of this study focused on the regional stratigraphic correlation of the Arkansas Novaculite (Mississippian–Devonian) incorporating total gamma-ray measurements. Outcrops and wells were examined and correlated from the frontal thrust belt at Black Knob Ridge to the southern flank of the Benton Uplift at Caddo Gap. Four informal members of the Arkansas Novaculite Fm (upper chert, Novaculite shale, laminated zone, Pine Top Chert) are defined. These petrophysical and lithologic members are consistent and persistent throughout the Ouachita Overthrust. We believe that the observed consistency in stratigraphy and facies provides a framework for deciphering important sedimentologic and structural complexities within the Thrust Belt.

Surface gamma-ray spectroscopy can also be applied to the assessment of source rock potential in the Ouachitas. The Polk Creek Shale (Silurian) was measured at the Stringtown Quarry at Black Knob Ridge utilizing the integrating spectrometer. Geochemical samples were collected and analyzed for total organic carbon (T.O.C.) and pyrolysis (S_2) at each station. Comparison of the spectral gamma log and geochemical results [reveals] that uranium and potassium values correlate directly with T.O.C. and S_2 values. These surface source rock data sets can be correlated to the subsurface. [194]

Influence of Thrust Imbrication on Thermal Maturation Within the Frontal Ouachitas, Arkansas and Oklahoma

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A critical question regarding the evolution of the frontal Ouachita thrust belt is whether maximum burial depths were attained during primary stratigraphic burial or during subsequent imbrication of thrust sheets. We can identify three types of thrust-related thermal anomalies by integrating vitrinite-reflectance data (R_o) for surface exposures with structural field mapping.

The first type of anomaly is referred to as thermal inversion. Strata within a hanging wall display higher levels of thermal maturity than footwall strata, even though the hanging wall is now at a higher structural level. Rocks of the hanging wall must have reached their maximum burial temperatures prior to the thrusting event, and they were later thrust over younger, "colder" strata. Thermal inversion is evident across the Y-City fault, where Jackfork/Johns Valley strata are thrust over the lower member of the Atoka Formation.

A second type of anomaly involves abnormal R_o gradients. There are localities where over 4000 m of lower Atoka strata are preserved, yet mean R_o values change only slightly up stratigraphic section. Following the Hood maturation model, some of these data require a geothermal gradient of less than 0.5°C/100 m, which is unrealistically low. Consequently, we suggest the changes in temperature were simply related to minor differences in the magnitude of thrust burial.

A final type of anomaly is evidently related to localized shear heating along discrete fault zones. In one notable example, Atokan shales developed a pencil cleavage in the immediate vicinity of the Y-City fault. The mean R_o value for these shales is 2.11%, which is significantly higher than for strata on either side of the fault (1.41% to 1.20%). We estimate that temperatures were elevated 50°C to 100°C above background values. [195]

The Impact of Mining on the Tar Creek Drainage Basin

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Tar Creek, a north to south flowing tributary of the Neosho River, drains 139.86 square kilometers in southeastern Kansas and northeastern Oklahoma. Over millenia a typical dendritic drainage pattern developed on the Boone Formation. With the discovery of lead and zinc deposits near the surface in the early 1900's, drill holes, mine shafts, chat piles, settling ponds, and railroad beds changed the drainage characteristics. With the collapse of mine shafts and mine caverns, surface water is being funneled into the mines rather than in channels over the surface. Air photo analysis and field investigations documented changes in the drainage characteristics in response to human activity. Presently, water from 31.08 square kilometers drains directly into the mines rather than through the drainage system. Channels draining into the mines will be diverted around mine openings in an effort to reduce inflow into the mines and slow the rate at which acid mine water reaches the surface. Potential changes in the drainage system, however, can still occur in response to new collapse depressions in the former mining area. In addition the removal of mine tailings (chat) for road material represents another modification of the drainage system. Analysis of the drainage system prior to human activity can aid in the reestablishment of channels through which water will flow to the Neosho River rather than into the abandoned mines. Surface inflow plus the accumulation of ground water in the abandoned mines contributed to the outflow of acid mine water—the condition that attracted national attention to this pollution problem. [196]

Barite Tufa from Zodletone Mountain, Southwestern Oklahoma

PAUL YOUNGER, CINDY PATTERSON, R. NOWELL DONOVAN, and ARTHUR W. HOUNSLOW, T. Boone Pickens, Jr. School of Geology, Oklahoma State University, Stillwater, OK 74078

A tepid water (c.22°C) sulphurous spring at the northern edge of Zodletone Mountain in Kiowa County is probably located on a major fault in the Wichita Frontal fault zone. Water emanating from the spring has a composition typical of oil field brines. Deposits associated with the spring include barite, calcite, gypsum and native sulphur. Sulphur is present as irregular nodules, gypsum as selenite crystals up to 3 cm in length and calcite as tufa. Three forms of barite are present: (a) laminated "travertine" consisting of coarse grained euhedral crystals with pronounced growth lines (suggesting periodic precipitation), (b) encrustations around organic remains (various plants). This form of barite is isopachous and shows growth lines. (c) cement precipitating around an existing calcareous tufa. This form of barite shows pendant

features suggestive of vadose precipitation. The principal areas of barite precipitation are no longer active. We speculate that the deposits are the product of the mixing of a barium-bearing connate brine and sulphate-rich ground water. [198]

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Permission of the authors to print the following abstract is gratefully acknowledged.

Geologic and Management Effects on Ground Water Quality of Oklahoma Grasslands

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Shallow well, water quality analyses were made in the Reddish Prairie and Rolling Red Plain land resource areas. Approximately 50 wells of $<$20 m depth were involved, and analyses included ammonium, nitrate, phosphate, sulfate, chloride, sodium, calcium, and magnesium. Changes in the chemical levels over two to four years were monitored, in order to relate ground water quality to causative factors such as management practices, oilfield activity and the predominance of the local geology. Chemical analyses of samples from the wells indicate, to date, that local geology and certain existing oilfield activity may cause high levels of chloride and sulfate. Generally acceptable levels of nitrate and phosphate have been found, but increases in ammonium have occurred at select well sites which are located in, or nearby, cattle feedlots, pastures, and farmsteads.

The University of Oklahoma

The following abstracts are from M.S. theses which have recently been added to the OU Geology and Geophysics Library.

Relation of Biofacies to Lithofacies in Interpreting Depositional Environments in the Pitkin Limestone (Mississippian) in Northeastern Oklahoma

ROBERT S. FABIAN, University of Oklahoma, Norman, OK

This thesis provides a detailed community analysis of the Pitkin Limestone (Chesterian) in northeastern Oklahoma. Three communities were identified and distinguished from each other based on faunal rank abundances and composition. Paleoenvironmental interpretations were made from the community and lithofacies information.

The *Ovatia–Sphenotus* Community is composed primarily of brachiopods and pelecypods. This community is associated with the mudstones and wackestones of the Pitkin. The community was located in the quiet waters and muddy substrate of the open marine shelf below normal wave base. Distribution of the community is widespread across the study area. The *Ovatia–Sphenotus* Community represents the initial stabilization and colonization stage in the total community's succession.

The *Pentremites–Composita* Community is composed of bryozoans, echinoderms and brachiopods. This community is associated with the bryozoan crinoidal packstones and grainstones of the Pitkin. The abundance of the stalked echinoderms and the bryozoan *Archimedes* indicates the community was located in shallow, open marine waters near normal wave base. The community is widely distributed across the study area and the thick accumulations indicate a long period of community stability. The *Pentremites–Composita* Community represents the diversification stage in the total community succession.

The third community is the *Ovatia–Diaphragmus* Community and is composed primarily of brachiopods, crinoids, and pelecypods. The community is associated with the mixed skeletal bioclastic lithofacies and the oolitic packstones. The disappearance of the corals, blastoids, and the reduced numbers of bryozoans indicate this was a more stressful environment than those of the previous community. This community lived in a moderately turbulent environment near normal wave base and in close proximity to the abundant ooid shoals. The community is also widely distributed across the study area and developed thick accumulations. The *Ovatia–Diaphragmus* Community represents a regressive stage in the total community's succession due to the greater effects of the physical environment on the fauna.

It is proposed that topographic highs in western Adair County (Clupper, 1978) and southern Cherokee County (Nageotte, 1981) affected the development and distribution of the communities during the Pitkin. The higher energy communities, the *Pentremites–Composita* and *Ovatia–Diaphragmus* Communities, developed earlier in the Pitkin in the areas associated with these highs. The initial development of these two communities on the basinward, southern and western sides of the highs suggests that the major ocean current patterns were from the south and west.

Coral Fauna and Carbonate Mound Development, Pitkin Formation (Chesterian), North America

GREGORY EDWARD WEBB, University of Oklahoma, Norman, OK

Two types of large carbonate mud mounds occur in the Pitkin Formation of northern Arkansas. Both types have as their primary framebuilders, thrombolites (nonlaminated cryptalgal structures), with associated bryozoans, crinozoans, and calcareous algae. They are distinguished from each other on the basis of their differing geometries and associated faunas. Type I mounds are the most numerous, and occur in Washington and Madison Counties, Arkansas. They consist of a complex of biolithites that alternately impinge upon, and are impinged upon, by the surrounding horizontal strata. The term "Christmas tree" has been applied to this distinctive geometry. The surrounding strata are largely derived independently of the mounds, and do not slope off of them. These mounds are interpreted as having had low original relief (less than 3 meters), with sea level being the limiting factor.

Type II mounds are less numerous and occur in Searcy County, Arkansas. They also consist of a complex of biolithites that alternately expand into, and retract out of, strata that are derived almost exclusively from the mounds themselves. They are interpreted as having had original relief of at least 6 meters, and are thus thought to have occurred in relatively deeper water than Type I mounds. The entire Type II mound complexes (including their contemporaneous flanking beds) are contained within strata that slope off of them, and are truncated up against them. They contain a different associated flora and fauna than do Type I mounds, the most conspicuous differences being in the composition of the coral fauna and in the greater abundance of phylloid calcareous algae.

The Pitkin mounds are significant in that they provide a faunal link between the well-known Waulsortian mounds of early Mississippian time and the abundant phylloid algal mounds of the Pennsylvanian Period. Waulsortian mounds may well be cryptalgal in origin, and contain associated bryozoans and crinozoans. Type I mounds, in the Pitkin Formation, contain the same fauna, but also contain scarce phylloid algae. Type II mounds, which occur higher in the Pitkin Formation, contain a similar fauna but contain an abundance of phylloid algae. Phylloid algae then predominate in the Pennsylvanian phylloid algal mounds.

The Pitkin Formation contains a diverse coral fauna. Eleven species in ten genera of rugose corals and five species in three genera of tabulate corals have been identified. This includes seven new species and two new genera of rugose corals. Although certain of the genera are distributed widely across the Pitkin outcrop belt, none could be considered truly cosmopolitan. A portion of the geographic distribution pattern may be a reflection of the stratigraphic distribution of the corals, which shows truncation to the north and west. The rest of the distribution pattern is better explained as the result of differing local environments.

Princeton University

Permission of the author to print the following abstract from an unpublished Ph.D. thesis is gratefully acknowledged.

Oolitic Ironstones and Associated Facies Within the Timbered Hills Group (Late Cambrian and Late(?) Cambrian), Wichita Mountain Area, Oklahoma

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Cambrian sedimentary rocks of the Wichita Mountain area, Oklahoma, record the oldest widespread development of the detrital quartz- and aluminum-rich oolitic ironstone facies. This type of oolitic ironstone first became common in the western United States in Middle to Late Cambrian time. The stage was set for the formation of these ironstones by an intense subaerial weathering episode which followed emplacement of the Carlton Rhyolite (Middle Cambrian(?)). In the Wichita Mountain area, this weathering episode produced an Fe- and Al-rich regolith above a saprolite several meters thick. The upper two meters of the saprolite are rich in kaolinite today. The oxidation state of iron oxides increases towards the top of the saprolite. Saprolite development apparently occurred in a reversely polarized magnetic field.

Sedimentation began with the deposition of lithic arenites, some of which contain spherical hematite ooids. An initial iron hydroxide mineralogy is inferred for these ooids on the basis of hydraulic equivalence and their spherical shape. A non-marine origin for these lithic arenites may be indicated by their immature composition, the absence of fossils, and their position at the base of a broadly transgressive sequence. If so, the spherical hematite ooids may be analagous to those forming today in Lake Chad.

A widespread marine transgression reached this area in Middle Late Cambrian time and removed most of the regolith. Mature, possibly tidally dominated strata, with bimodal or polymodal dip directions, form the first recognizable marine unit. Further marine transgression set the stage for the formation of a second oolitic ironstone. Ellipsoidal ooids, now composed of hematite, goethite, chamosite(?), and phosphate, were developed in local sediment-starved areas and transported to depositional sites in sand waves. The initial composition of many of the ellipsoidal ooids is inferred to have been a plastic Fe–Si–Al gel. This episode was followed by further marine transgression. Concurrently, listric normal faulting established this area as the southwestern margin of the incipient Anadarko Basin. Fecal debris composed of kaolinitic clay

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formed a major fraction of the sediment which accumulated during this time. Before burial, partial conversion to glauconite occurred at the sediment-water interface. The glauconitization also altered carbonate particles and rhyolite fragments. On a regional scale, the widespread development of glauconite and allied minerals was fostered by the first appearance of fecal pellel producers.

By analogy with Tertiary oolitic ironstones, an intensely weathered source area which once contained laterites and bauxites is inferred to be present within 100 to 300 km of the Oklahoma ironstone occurrence. These laterite- and bauxite-bearing source areas have probably been extensively resilicated.