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Geologic controls of uranium deposition, Karnes County, Texas

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Abstract

The geologic controls for the formation of the epigenetic south Texas uranium deposits are (1) source rock, (2) leaching, (3) transport, (4) host rock, (5) reductant, and (6) preservation. The primary uranium source rock for the south Texas deposits is the Miocene Catahoula Tuff. It contains about 2.7 ppm uranium, much lower than normal for rhyolitic tuffaceous material, and its Th/U is 5.6, also indicating uranium depletion. The uranium was apparently dissolved during mildly oxidizing and alkaline conditions associated with dry-climate weathering and caliche formation. Beach and fluvial sandstone units exposed in areas of Catahoula drainage provided subsurface conduits for the movement of uranium-bearing water into the host rocks. For a few deposits the uranium-bearing water was transported mainly in streams or along joints and faults. Fluvial and beach sandstone deposits in the Whitsett Formation of the upper Eocene Jackson Group are the main host rocks. Some mudstone and lignite units in contact with the sandstone units also contained ore. Carbonized wood, found in or near most of the host sandstone bodies, was apparently sufficient for a chemical reductant; but, for some of the deposits, nearby oil and gas fields suggest that petrolic gases may have caused the reduction necessary for the precipitation of the uranium. The deposits were preserved as long as they were not invaded by large quantities of oxidizing ground water or destroyed by erosion.

Geologic controls of uranium deposition, Karnes County, Texas

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Introduction

The geologic controls for the formation of the epigenetic south Texas uranium deposits are (1) source rock, (2) leaching, (3) transport, (4) host rock, (5) reductant, and (6) preservation. The purpose of this report is to evaluate and describe each of these controls for the Karnes County area (Eargle and others, 1975) and some of the controls for individual mines in the unoxidized trend. The geology of the oxidized ore mines, which are located about 2 km updip, northwest of the unoxidized trend, is discussed by Bunker and Mackallor (1973).

This text is a modified version of a lecture presented on August 8, 1975, before the Rocky Mountain Association of Petroleum Geologists, and on November 20, 1975, before a class at the Colorado School of Mines.

Geologic setting

The Karnes County uranium deposits were found in the Whitsett Formation of the upper Eocene Jackson Group (figs. 1, 2). The Whitsett Formation consists of alternating sandstone and mustone members that are, in ascending order, the Dilworth Sandstone, Conquista Clay, Deweesville Sandstone, Dubose Clay, Tordilla Sandstone, and Fashing Clay (fig. 2) (Eargle, 1972). The sandstone members were deposited for the most part in the beach environment and the mudstone members, in lagoonal or continental environments (Dickinson, 1976). Both the mudstone and beach members have been transected by sandstone-filled fluvial channels (fig. 2). The Whitsett was deposited on the northwest flank of the Gulf coast geosyncline. The beds thicken and dip gently toward the gulf, to the southeast. Large-scale faulting generally parallels the gulf shoreline. Additional information on the stratigraphy of the area may be found in the works of Eargle and his coworkers (Eargle and others, 1971; Eargle and Weeks, 1973; Eargle and others, 1975).

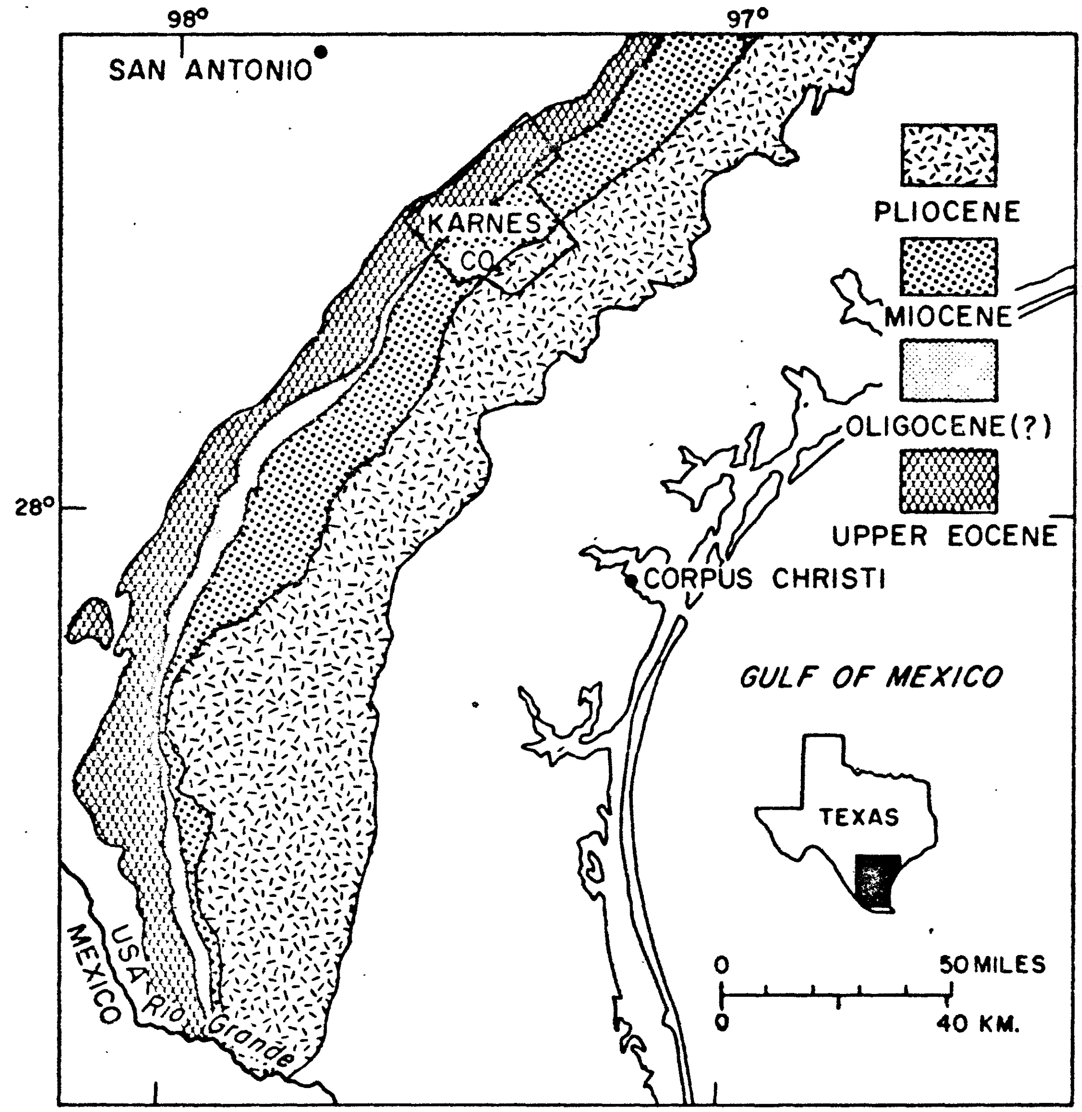

FIGURE I.--GENERALIZED GEOLOGIC MAP OF THE COASTAL PLAIN OF SOUTH TEXAS

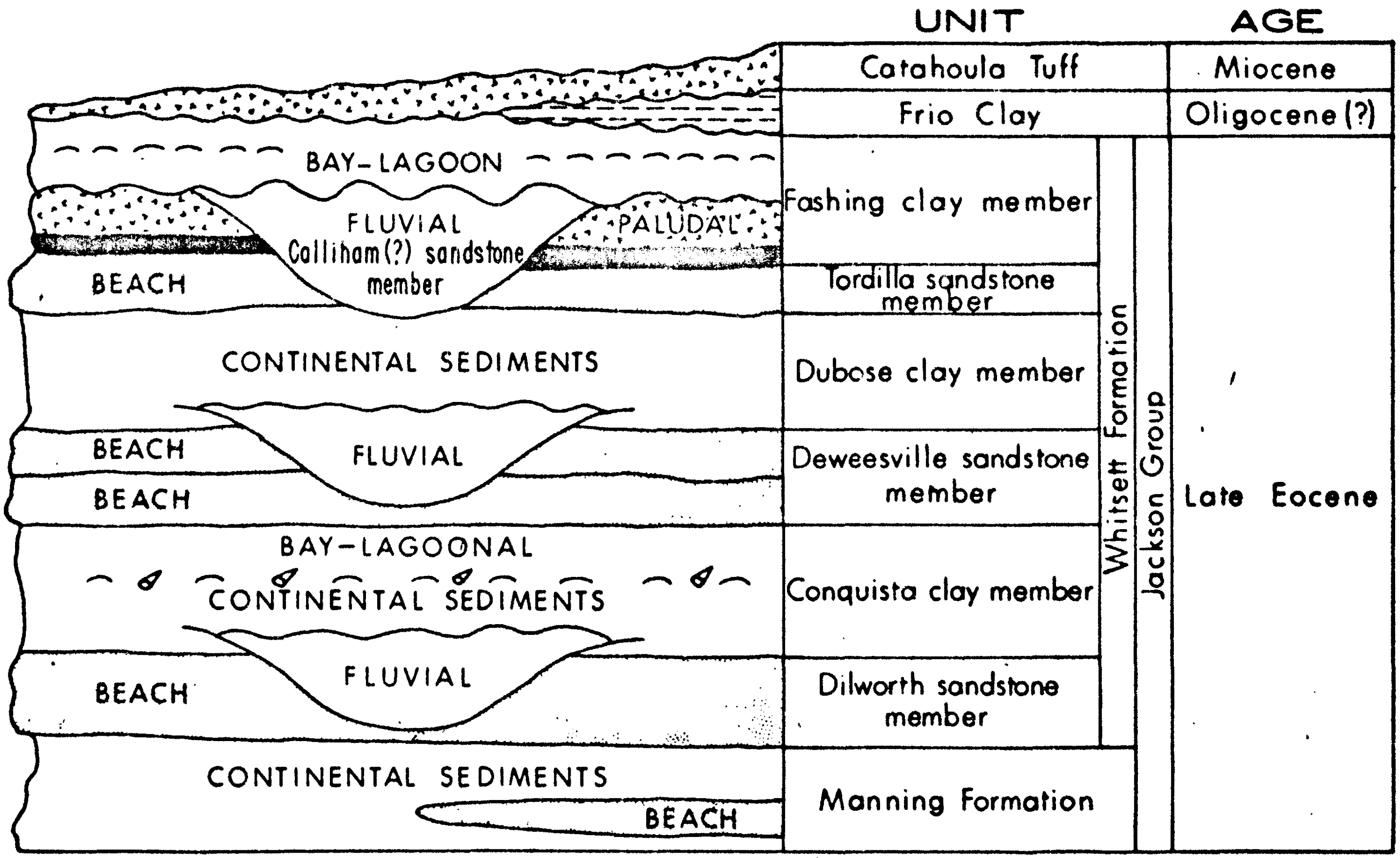

FIGURE 2.--SCHEMATIC STRATIGRAPHIC DIAGRAM.

KAD/BOD, APRIL 1, 1976

Source rock

The ultimate source rock for the uranium in Karnes County and in south Texas in general is believed to be the Miocene Catahoula Tuff (Eargle and Weeks, 1973). This conclusion is based on (a) the discrepancy between the assumed original uranium content and the present uranium content of the tuff, (b) the thorium-to-uranium ratio, and (c) the lack of other potential source rocks. The present uranium content of the Catahoula is about 3 ppm. Fifteen samples from near the Manka mine (pl. 1), analyzed by the neutron-activation method, average 2.7 ppm uranium. On the basis of 146 radiometric measurements, Duex (1971) found that the Catahoula averaged 3 ppm. According to Adams (1954) the uranium content of acidic volcanic tuffs is about 5.6 ppm, or nearly twice the amount found in the Catahoula. Furthermore, Gottfried, Moore, and Caemerer (1962) reported as much as 45 ppm uranium in alkalic igneous rocks in the Big Bend region of Texas, the supposed source of the south Texas volcanics. Dickinson (1975) reports 10 ppm uranium and 32 ppm thorium from below the depth of soil leaching in a relatively unaltered ash bed in the Fashing Clay Member of the Whitsett Formation. These figures are believed to represent the original content of the ash, the source of which was probably similar to that of the Catahoula Tuff. Moxham (1964) suggested, on the basis of total-count, airborne radioactive studies, that radioelements have been removed from the Catahoula.

A high thorium-to-uranium ratio in the Catahoula may indicate a loss of uranium. This conclusion is based on the assumption that thorium and uranium are present in alkalic igneous rocks in a ratio of about 3 or 4 times more thorium than uranium (Adams, 1954). The thorium is believed to be more stable in the source rock, and it tends to remain in the source rock when the uranium is leached. The average Th/U for 15 samples analyzed by neutron-activation of the Catahoula at the Manka mine is 5.6. The Th/U calculated from the radiometric data of Duex (1971) is 3.0 and does not indicate preferential uranium leaching.

Another source suggested by Weeks and Eargle (1963) is tuffaceous material in the Jackson Group. Thirty-nine samples of tuffaceous mudstone from the Whitsett Formation that were analyzed by neutron-activation averaged 13 ppm uranium, and the Th/U averaged 2.4, suggesting that the tuffaceous material of the Whitsett did not substantially contribute to the uranium deposits.

An oxidized ore trend parallels the unoxidized trend about 3 km to the northwest. The weathering in this trend probably provided uranium-bearing water that fed some of the unoxidized deposits and formed a secondary source for them. This process may have been similar to Gruner's multiple-migration-accretion hypothesis (Gruner, 1956). The oxidized trend probably represents an earlier unoxidized trend that has since been partly destroyed by erosion.

Leaching

The uranium was apparently leached from the Catahoula Tuff by a moderately oxidizing alkaline solution (Weeks and Eargle, 1963). Garrels (1957) described how these conditions were formed during diagenetic alteration of volcanic glass, and Eargle and Weeks (1973) suggested that these conditions were enhanced by dry-climate weathering. Arid or semi-arid environments have occurred at least intermittently since the Miocene in south Texas (Eargle and others, 1975). Uranium disequilibrium studies by Rosholt (1959, 1963) indicated that small amounts of uranium have mobilized and were redeposited as recently as 10,000 years ago. Studies of uranium distribution in soils in south Texas by Dickinson (1975) indicate leaching during calichification. Several periods of caliche-weathering probably supplied abundant carbonate ions to the system, facilitating uranium leaching.

Transportation

After entering solution, the uranium is transported by surface drainage or underground flow to the depositional site. For near-surface sites this flow may be largely by streams, and for other sites it may be primarily or entirely underground. Where underground flow occurs, a permeable rock or a fault acts as a conduit. In Karnes County some conduits are beach sandstone units that trend parallel to the strike or fluvial units that trend obliquely to it. At other deposits joints or low-displacements faults may have acted as conduits. The sandstone of the beach facies is fine grained and well sorted; that of the fluvial facies is also well sorted but is medium grained.

Host rock

The host rock may be nearly the same as the conduit rock, but it is the rock in which the oxidation-reduction front is located at the time of ore deposition. Typically, however, the uranium enrichment extends beyond the most permeable rock and may include some siltstone or mudstone. In fact, some authors (Weeks and Eargle, 1963) have proposed that permeability barriers are an important aspect of a host rock and tend to retard migrating ground water to allow time for the uranium to precipitate. Large quantities of water must, nevertheless, pass through the host rock to bring in the uranium.

Reductant

Reductants may be autogenic, generated from within the host rock, or allogenic, coming from outside the host rock. Both kinds may be important in Karnes County. Carbonized plant material is a common autogenic reductant in the uranium host rocks of both beach and fluvial origin. Weeks and Eargle (1963) have postulated that hydrogen sulfide or some other petrolic gas was an important reductant for the uranium deposits of south Texas. Water-soluble organic carbonaceous material may also have served as a reductant in some deposits. The gaseous and liquid reductants originated outside the host and are classed as allogenic reductants.

Important geological implications surround the distinction between allogenic and autogenic reductants. In the case of autogenic reductants, the reductant is consumed by the continued entrance of oxygenated water and the oxidation-reduction front migrates. Migration of the fronts produces large oxidized tongues, typical, for instance, of the Wyoming deposits. Allogenic reductants, on the other hand, are renewable, and a dynamic equilibrium exists between the entrance into the system of oxygen via the uranium-bearing water and the entrance of reductant from an outside source. With an allogenic reductant a stationary oxidation-reduction front can form without the development of an extensive oxidized tongue. Such a stationary front seems especially likely where a strong allogenic reductant enters through a stationary geologic feature such as a joint or fault. Most unoxidized deposits in Karnes County are found at about the same depth, about 25 m, which is about the depth of the present water table. It is not known where the water table was at the time of deposition, but the occurrence of many of the Karnes area deposits at the same general elevation suggests a relation to the water table.

Preservation

The uranium deposits were preserved as long as they were not invaded by large quantities of oxidizing water or destroyed by erosion.

Weeks and Eargle (1963) have suggested that a dry climate has aided in preserving the south Texas uranium deposits. They further suggested that the caliche cap that occupies most of the uranium area helped preserve the deposits by restricting the leaching. The caliche cap, which is being destroyed by the present subhumid to semiarid climate, was radiocarbon dated at 18,000 years old. If a dry climate is necessary for preservation, then dry climates must have persisted for at least 240,000 years, because many of the deposits are in radioactive equilibrium. These arguments probably apply only to the deposits within 100 or 200 m of the surface. More deeply buried deposits are probably not affected much by the climate.

Some of the Karnes County deposits may have been dissolved during wet periods and redeposited farther downdip--perhaps in another sandstone unit--near the water table where a reducing environment was encountered. This process is probably similar to the multiple-accretion hypothesis of Gruner (1956). A large influx of oxidizing meteoric water for a long period would tend to completely remove the uranium from the system. The lack of uranium deposits in the central, more permeable parts of some of the large channel deposits, such as the one in the Miocene Oakville Sandstone, south of Karnes County (Eargle and others, 1975), may result from destruction by the movement of large quantities of ground water through the deposit. This ground water may also have prevented the formation of deposits in excessively permeable rocks. The oxidation of an earlier roll-front deposit in the F. Brysch mine by movement of large amounts of water through a fluvial sandstone conduit may represent incipient destruction of this deposit (Dickinson and Sullivan, 1976).

Controls for individual deposits

The geologic controls for individual deposits in the Karnes area are discussed below. The name used for each deposit is the name of the mine or one of the mines within the deposit. The oxidized deposits along the Deweesville outcrop are not evaluated in this study.

Pfeil The Pfeil deposit extended through the Pfeil, Wright, McGrady, and most of the Weddington mines of Continental Oil Company (pl. 1). The uranium-bearing solutions probably entered through the outcropping Tordilla Sandstone and through the Kellner channel, which is of Fashing age. The oxidized tongue lies to the northwest and the reduced area lies to the southeast. The convex side of the ore roll points southeastward. The roll-front may have migrated from the outcrop to its present position in response to the downdip movement of uranium-bearing oxygenated ground water within the Tordilla, but the offset between this deposit and the Butler-Galen deposit to the north is a strong indication that the deposition was controlled, at least in part, by the Kellner channel. The Fashing fault was projected into the area (Eargle and others, 1975), but there is no proof that it extends that far or, if it does, where it is located. The reductant for the Pfeil deposit was probably carbonized plant material in or near the host rock. No connection between this deposit and a possible petrolic reductant is apparent, though it cannot be ruled out. The greater downdip migration of this deposit compared with the Butler-Galen deposit may result from a weaker reductant in this area.

Butler-Galen The Butler-Galen deposit was mined from a series of mines beginning on the southwest with the Tenneco part of the Weddington and extending northeastward through the Susquehanna part of the Weddington, the Butler, the Turner, and the Galen mines (pl. 1). Water-bearing uranium leached from the Catahoula entered the deposit via the Kellner channel at the southwest end and through the Tordilla Sandstone Member from its updip outcrop edge. Some uranium may have been dissolved from or passed through the Pawelek deposit. (See p. 13.) Host rocks are the Tordilla Sandstone Member and the Kellner channel deposit of the Fashing Clay Member. The convex side of the roll lies to the southeast and the oxidized tongue lies to the northwest. In general, the movement of water through the deposit was from northwest to southeast. Movement of uranium-bearing water through the deposit was restricted along the northeast end, where porosity was greatly reduced by diagenetic siliceous cement. A well-developed roll was not present in the channel sediment on the Kellner end of the deposit. The reductant was probably carbonized plant material in the host rock and petrolic gases. Oil- and gas-producing holes penetrate the deposit and are found in the area just north of the deposit (pl. 1).

Sickenius Conquista Creek, which drains a large area of Catahoula terrane, and an area that contained oxidized uranium ore, crosses the Tordilla outcrop at the northeast end of the deposit (pl. 1). The uranium-bearing Conquista Creek waters apparently entered the host rock at or near this juncture. This conclusion ties the age of the ore emplacement to the modern drainage pattern. This tie is further substantiated by disequilibrium between uranium and its daughter products that indicates an age less than about a quarter million years for the uranium in this mine. During the early mining on this property, only the near-surface ore from the northeast part of the mine was removed. This ore was mostly lignite in the lower part of the Fashing Clay Member. Later, unoxidized ore from the Tordilla Sandstone Member was removed from the south and west portions of the mine. Siliceous cement, including clinoptilolite and cristobalite, apparently limited mineralization to the southwest along the trend (pl. 1). The siliceous "caprock" in the southwest end of the mine was broken up with explosives prior to mining.

Kellner Uranium-bearing waters from the Catahoula drainage entered a porous channel deposit in the Fashing Clay Member, herein termed the Kellner channel (pl. 1), and traveled downdip southeastward to the depositional site where both medium-grained sandstone and underlying mudstone deposits were mineralized. The sandstone is well-sorted, medium-grained zeolitized arkose. This ore consisted of three separate bodies and did not conform to the classical ore-roll shape. Although the reductant is largely unknown, carbonized leaves and other matter were contained in the host rock.

Rosenbrock The Rosenbrock uranium ore body was deposited in the Kellner channel of the Fashing Clay Member about three km east of the Kellner mine. The ore roll is at a depth ranging from 70 to 90 m. The mine for this deposit is the deepest open-pit uranium mine in south Texas as of January 1, 1976, and at that time it was still being stripped. The oxidized side of the ore roll is to the north. The channel is eroded into and is at approximately the same stratigraphic position as the Tordilla Sandstone (pl. 2). The uranium-bearing water apparently entered the deposit from the Kellner channel, and the roll front may have migrated down this channel. Lineaments noted on aerial photographs intersect the deposit. They are believed to be joints or low-displacement faults that may have affected movement of ground water or reductants at the deposit. The deposit also lies in a slight downflexed zone (pl. 2).

Brysch The Brysch deposit was apparently formed where uranium-bearing water of the Conquista Creek flows over the basal lignite of the Fashing Clay and the Tordilla Sandstone Members. The mine was completely filled with water at the time it was seen by the writer, and only the waste piles were available for study.

Mocszygemba-Manka The Mocszygemba-Manka deposit (pl. 1) was found in an area where the Catahoula unconformably overlies the lower part of the Fashing Clay and the Tordilla Sandstone Members. Channels at the base of the Catahoula were probably important in localizing uranium-bearing ground-water flow. A lignitic layer at the base of the Fashing and carbonaceous material in the Tordilla host rock probably provided the reductant.

Stoeltje The Tordilla Sandstone Member is the host rock for the Stoeltje deposit, which lies just north of the Hobson oil field (pl. 1). The Tordilla is overlain by the Fashing Clay Member, which, in turn, is overlain unconformably by fluvial deposits of the Catahoula Tuff. The deposit is transected by joints along which uranium-bearing water probably entered. One joint contains a clay deposit ranging from 2 to 10 cm in thickness that reportedly predated and locally limited uranium emplacement. The Tordilla Sandstone Member contains grains of quartz, feldspar, and volcanic glass, and is weakly cemented with montmorillonite. The sandstone is largely crossbedded and contains Ophiomorpha and clasts of lignite and clay. The mudstone unit overlying the basal lignitic layer of the Fashing Clay in the Stoeltje mine is saturated with water-soluble organic matter (J. Leventhal, oral commun., 1975) that may have been the reducing agent for this ore body. The organic material is leached out in the vicinity of the joints. The proximity of the Hobson oil field suggests a petrolic reductant, but the abundance of organic material indicates otherwise. The configuration of the ore roll was somewhat contorted and is not completely known to the writer.

Brown The Brown deposit is geologically situated similarly to the Mosczygemba-Manka deposit. The Catahoula, with fluvial channels at its base, unconformably overlies the Fashing Clay Member. The channels in the base of the Catahoula seem to have been important in localizing the mineralization. The host rock, unlike that in most of the Karnes area deposits, consists of thinly interbedded sandstone or siltstone and claystone. The host rock may have been laid down under tidal-flat or lacustrine conditions.

Pawelek The uranium host rock in the Pawelek deposit (pl. 1) was mostly a lignite at the base of the Fashing Clay Member that directly overlies the Tordilla Sandstone Member. A small body of oxidized uranium ore was removed from the sandstone below the lignite. The average depth to the ore was about 15 m. The host rock was above the water table. Uranium-bearing water from the Catahoula terrane apparently entered along the outcrop of the Fashing Clay Member, perhaps through the lignite itself.

Lauw and Beiker The Lauw and Beiker deposits are discussed together, even though they are nearly 1 1/2 km apart (pl. 1), because the host rocks are both channel deposits believed to be part of the same channel. This channel is in the Dubose Clay Member and is herein termed the Lauw channel. It may have eroded in places into the underlying Deweesville Sandstone Member. The uranium-bearing water probably entered the channel deposit in the area east of Tordilla Hill, where it apparently crops out. The channel deposit has not been definitely recognized in surface exposures owing to soil cover in the area, but a small outcrop of crossbedded sandstone (Twdc, pl. 1) in a roadcut along highway FM 791 at the base of Tordilla Hill may be in this channel. The uranium was in an ore roll that is unoxidized on the northwest side, opposite of the other rolls in the Karnes area. The updip movement of the uranium water was probably caused by the movement of the water from the Lauw channel to the stratigraphically lower Deweesville Sandstone Member. The reductant in these deposits is probably the carbonized wood in the host rock. The channel sandstone is fine to medium grained, is crossbedded, and contains *Ophiomorpha*, suggesting that the channel was a distributary channel not far from the coast.

Searcy The Searcy deposit lies in the divide between Conquista and Scared Dog Creeks, just south of the Lucket deposit, an oxidized ore body in the Deweesville. The host rock for the Searcy is also the Deweesville, and the uranium-bearing water probably resulted from solution of uranium during weathering of deposits in the oxidized trend approximately 100 m to the northwest. The Deweesville Sandstone was deposited in a beach and back-beach environment. It contains abundant carbonized plant matter, an ample source of reductant. The configuration of the roll in this deposit is controlled by a thin mudstone unit within the beach sequence, believed to have been deposited in a hurricane washover or tidal pond.

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