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Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

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Dear Fred:

This letter constitutes the trip report for Williams and Associates, Inc. for the August 5-8, 1985, tripto Austin, Texas. Dr. Roy Williams, Dr. John Sharp, and Mr. Gerry Winter attended the workshop. The NRC workshop on the examination of Palo Duro cores convened in the afternoon of August 5 at the facilities of the Texas Bureau of Economic Geology. The meeting introduction was presented by Mr. Robert Johnson (NRC). Dr. Ed Bingler (Deputy Director, Texas Bureau of Economic Geology) and Mr. John Peck (representative for Stone and Webster Engineering Co.). Mr. Steve Frishman was present representing the Office of the Governor of Texas. Mr. Don McReynolds was present representing the High Plains Water District. Ms. Margaret Hart (Texas Department of Water Resources) attended the meeting. A full attendance list for the meeting is appended to cur trip report. Ms. Jo-Ann Sherwin served as the on-site representative for DOE at this meeting. Dr. John Trapp provided a brief introduction with respect to the interests of the NRC and the work being conducted in the Palo Duro Basin.

Mr. John Peck (SWEC) presented an overview of the Palo Duro Basin geology. He stated that the basin is approximately 10,000 ft thick with approximately 2,500 ft of evaporites which includes halite and anhydrite. He pointed out the well locations in Deaf Smith, Randall, and Swisher Counties. Mr. Peck stated that the Pennzoil Black #1 is a test well that was drilled last year. The Texas Bureau of Economic Geology (TBEG) and SWEC have obtained the geophysical logs for this well; core have not been obtained for this well.

Mr. Peck provided a description of the geologic section for the basin. Mr. Peck stated that there are no Jurassic sediments in the Palo Duro Basin. Salado salt is not found in Deaf Smith County. There is approximately 160 ft of salt in San Andres unit

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4. The Wichita Group consists mainly of anhydrite. Pennsylvanian sediments overlie the Precambrian in Deaf Smith County. Dr. Trapp (NRC) questioned whether the relationship between geologic structure and the drill holes would be addressed in the meeting. Mr. Peck stated that they did not plan to address the correlation or relationship between the drill holes and geologic structure.

Mr. Phil Murphy (SWEC) discussed the faults found in the Precambrian in the Palo Duro Basin. The structures associated with the faults apparently die out as depth into the section decreases. They found no faults which cut the site in Deaf Smith County. The salt units die out in Carson County either due to deposition or dissolution. There is an abnormally thin layer of the San Andres in this area. Oil producing zones in the Panhandle Oil and Gas Field are mainly from the Granite Wash and are associated with folds and faults. Dr. Williams questioned whether the units were broken down stratigraphically or hydrostratigraphically. Mr. Murphy responded that the units are being broken down based on stratigraphy and on porosity in the Pennsylvania and Wolfcamp Series. Dr. Trapp questioned whether the faults extend through the Ogallala at the John Ray Dome. Mr. Murphy responded that no one knows because no one can get on the ranch on which the dome is located to investigate.

Mr. Ruppel (TBEG) discussed the origin of the Permian evaporites. He noted that the structural axis is east-west but the depositional axis is north-south. He broke the units down into six basic units for further discussion. The first unit is the Ordovician and Cambrian rocks which underlie the whole area. The second unit consists of the Mississippian strata. The third unit consists of the Wolfcamp and Pennsylvanian strata. The Permian strata make up unit four. The fifth unit consists of the Dockum and Dewey Lake strata. Unit six consists of the Quaternary and Tertiary units. He pointed out that Mr. Conti is working on the lateral continuity of porosity and permeability in the basin. Mr. Ruppel pointed out that the strata are heterogeneous even with the current limited well control. The Ellenburger Group is missing from most of the basin. The sub Wichita section show evidence of downdropping in Brisco County while uplift is evident at the Amarillo Uplift. Significant clastics entered the basin up through the mid Wolfcamp. Mr. Ruppel stated that the basin was poorly defined but the definition was better by late Pennsylvanian. Mr. Winter questioned whether there was a significant degree of lateral continuity in the fan delta system south of the Amarillo Uplift as the block diagrams implied discontinuity between the outwash deposits. Mr. Ruppel responded that poor control exists in the area but there does appear to be good lateral continuity of the deposits.

Ms. Hovorka disagreed with Mr. Ruppel on the nature of the depositional environment between the Wichita Group and the Tubb Formation. The Tubb Formation progresses across the basin and also contains salt units. Mr. Ruppel stated that he is not sure the sabkha model is appropriate for describing the depositional system for the salt sequence. He stated that the sabkha model appears to be for a smaller areal expanse than that associated with the evaporite sequence in the Palo Duro Basin. He stated that the Glorieta Formation was characterized by facies changes. The Flower Pot unit which primarily occurs in Oklahoma is equivalent to the San Andres cycle 4. The sections show good lateral continuity for at least 177 miles in the Glorieta through the White Horse units. The San Andres cycle consists of a black anhydritic mudstone at the base which is a dissolution remnant. A schematic diagram was shown at this time to illustrate the general depositional environment associated with the Palo Duro Basin. The deeper waters are associated with a gypsum brine while the brine pool between deeper water and exposed flats results in bedded salt deposit. Exposed flats result in a mud-salt deposit. Ms. Hovorak stated that she does not believe the sabkha model is appropriate due to the large areal extent of the Palo Duro Basin. She believes that sabkha can be associated with an approximate 10 km zone wherein the depositional area migrated back and forth.

Mr. Davidson described the core facilities located at the Texas Bureau of Economic Geology. Mr. Davidson stated that over 55,000 wells are represented by drill cuttings at the facility. The Bureau began working on the DOE test well core in 1978. The have approximately 52,000 ft of core at this time. They completed a computer based core logging system in 1982. Core boxes have a bar code that can be read by a laser reader.

Ms. Hovorka provided a handout of material describing the depositional environment in the Palo Duro Basin. She stated that clastics make up approximately half of the evaporite sequence. The clastics are statistically the same in the evaporite section. There is a bimodal distribution of clay and silt size particles in the siltstone. The real porosity appears to occur in the dolomicrites; Stone and Webster Engineering Co. measured a maximum of 6 percent porosity in the dolomicrites. Ms. Hovorka's presentation was accompanied by a number of thin section slides and figures.

Ms. Hovorka continued her discussion of the Palo Duro Basin on August 6. She stated that the limestone normally is found in a salt cycle but this limestone is not present in San Andres units 2 and 4. The middle San Andres units do not contain some halite units. Salt cycles can range in thickness from less than 1 m up to 200 ft. Typical fabrics in halite include A-chevron, vertical

crystals, color bands and dissolution surfaces. (This is only a partial list of the typical fabric designations used by Ms. Hovorka.)

Ms. Hovorka stated that the dark color bands that occur in salt cross sections are clay, organics, and anhydrite. The dark zones in chevron anhydrite replacement contain abundant fluid inclusions. The isotopic compositions and inclusions may be mixtures of meteoric water and sea water. The inclusions can be 1 mm across or so small as to be indistinguishably.

Ms. Hovorka stated that 50 percent of the particles in the mudstones are silt size while 50 percent are clay size. A chaotic mudstone is probably due to karst features occurring in the salt which allow the downward movement of mudstones into the fractures. The source of the mudstones is unknown at this time. Aeolian processes appear to be significant with fluvial influences having a minor impact on deposition. The salt cycles could be pods with little lateral continuity; however, Ms. Hovorka has found that the units are laterally traceable. A question was posed by Mr. Lee (NRC) concerning the internal correlation of marker beds above unit 4 to the process used by Ms. Hovorka in her correlations. Ms. Hovorka stated that the use of a high marker shifts the correlations and is not used in the correlations presented in the meeting. Ms. Hovorka stated that using the mudstone as a marker bed gives a consistent result. She stated, in response to a question, that a repository placed in a salt cycle will encounter a few mudstone beds.

Ms. Hovorka stated that karst pits appear to form in a subareal exposure where rain eroded the surface: the pit filled with residue or recrystalized salt. The vertical scale of the karst features is 10^{0} to 10^{-2} m. She stated that there are geochemistry problems associated with this interpretation since no meteoric water inclusions have been found and the bromine content does not fit the model. She stated that the pits are up to 2 m in depth.

Mr. Cummings (Engineers International) asked how the depth varied for the different depositional environments. Ms. Hovorka responded that the depositional system ranged from 1 to approximately 30 m for the halite through carbonate sequence. Dr. Williams questioned whether halite dissolution in the Permian Basin was relevant to the performance consideration in the context of a 10,000 year travel time. Ms. Hovorka responded that she considered the dissolution aspect to be irrelevant to the 10,000 year criteria.

Dr. Kreitler (TBEG) discussed the wells used to investigate salt dissolution. Dr. Kreitler noted that peripheral dissolution

rates generally are considered to be greater than interior dissolution rates. He stated that this rate difference is probably due to the greater hydraulic gradient that is likely to be present near the caprock escarpment as opposed to the interior hydraulic gradients. The Harmon and Detten wells were constructed for evaluation of the interior dissolution zone. The Mansfield and Sawyer wells were constructed to investigate the peripheral dissolution zone. Dr. Kreitler noted that different salt units have varying positions of their dissolution front resulting in varying lateral extents for each of the salt units. The Mansfield and Sawyer wells were mud rotary drilled, cased, and grouted to the top of the dissolution zone. The actual zone to be tested was drilled with air rotary using foam; the well was deepened by drilling through the grout plug at the bottom of the casing. The well was extended into the section which was ultimately screened for pump testing. Dr. Kreitler noted that they could not pump the wells (Mansfield and Sawyer) dry with a 10 to 15 gpm submersible pump. He noted that the δO^{18} and δ D isotopic values for the peripheral dissolution wells fall on the meteoric line. He stated that there was a percentage of Carbon-14 present in the samples so that the waters tested were probably less than 50,000 years old. The approximate age at the Sawyer well is 10,000 years; the approximate age at the Mansfield wells is 19,000 years.

Dr. Kreitler stated that the productivity of the interior wells (Harmon and Detten) was much lower than the productivity of the peripheral dissolution wells. He noted that the pH of the Detten well was 11.5 which raises questions as to the validity of the sample obtained from this well. He noted that, if valid, the water sample falls on the meteoric line. These two interior wells were swabbed dry and then allowed to refill for purposes of determining hydraulic parameters. The yield of these wells is too low to conduct a constant discharge test with the submersible pump.

Ms. Hovorka discussed the dissolution above the San Andres. She stated that gypsum fills the fractures which occur in the siltstone; the fractures apparently were created due to collapse from beneath the siltstones. Ms. Hovorka noted that they have found a unique dolomite with multifaceted crystals in the halite along with anhydrite. This unique dolomite was found in thin sections made from Sawyer dissolution well core. Ms. Hovorka stated that the dolomite crystals that form in salts at shallower depths probably are due to diagenesis.

Mr. Lamb (SWEC) discussed the classification schemes under development for the Palo Duro Basin. The classification schemes are being developed to accommodate engineering characteristics in conjunction with the correlatable geologic scheme. He stated

that correlations between geophysical logs and core can be 5 to 10 ft off due to the core loss record keeping procedures used in the Palo Duro Basin. He stated that they are trying to correct this problem. Mr. Lamb noted that Bendix has been studying the geophysical logs with respect to identifying clay mineralogy. SWEC has conducted a few porosity and permeability tests. These tests have been secondary to the engineering property tests that SWEC has been conducting on core samples. Mr. Lamb noted that very little soil testing has been conducted; SWEC is waiting to conduct such work on site. Mr. Lee (NRC) questioned the source of the criteria for sample testing. Mr. Lamb responded that most core are of sufficient integrity to facilitate testing. SWEC has avoided testing multiple layer cores (8 inch core samples are used). Mr. Lamb, in response to Mr. Pearring's (NRC) question, stated that core tests were conducted under ambient temperature conditions. Mr. Lamb noted that other groups are studying the thermal properties of the core.

Mr. Lamb stated that SWEC is trying to relate laboratory tests to geophysical logs because laboratory tests are limited in number. SWEC has found that they can correlate with 95 percent confidence the tracing of engineering properties from well to well based on geophysical logs. Mr. Cummings (Engineers International) asked Mr. Lamb whether the hydrofracturing tests are appropriate for determining minimum and maximum stresses. Mr. Lamb responded that he considered the hydrofracturing tests to be useless for determining maximum stress but that such tests are adequate for determining the minimum stress in situ. Mr. Lamb stated that the minimum horizontal stress calculated for the unit 4 salt in the lower San Andres is questionable. The validity of the test is questionable because the hole had been allowed to stand with drilling mud in place for a long period of time. He believes that there may be a differential stress in the salt but the data are not conclusive.

Mr. Senseny (RE/SPEC) discussed the work their company is doing with respect to eventual performance assessment. They are running Brazilian, unconfined compression, triaxial compression, and creep tests at constant temperatures and pressures. They have conducted some elevated temperature tests but only on unit 4 and unit 5 at repository levels. These elevated temperature tests were conducted at 25, 50, 75, 100, and 200 degrees. (we believe the temperatures were given in degrees Centigrade although it was not stated.) The elevated temperature tests were conducted mainly on the G and J Friemel wells. The data from the tests have been published; three of the reports are ONWI-450, BMI/ONWI-549, and RSI-0252. Mr. Senseny stated that they have not been able to correlate the purity of the salt to the engineering properties which they have tested. They tried to base correlations on 1) halite, 2) 10 percent clay, 3) 20 percent

clay, and 4) anhydrite. The graphs presented by Mr. Senseny illustrated the apparent lack of correlation.

The group reconvened after lunch at which time Ms. Hovorka described the well core which had been laid out for inspection. The group proceeded to the core laboratory; the remainder of the day was spent reviewing and discussing the core with Texas Bureau of Economic Geology personnel.

The group continued their examination of the core on the morning of August 7. The group reconvened in the afternoon to complete discussions. Ms. Sherwin discussed the relationship between the DOE and the NRC. Mr. Johnson (NRC) provided input to help clarify the relationship between the two organizations. She discussed the relationship between the various working groups and technical departments within ONWI and the DOE prime contractors. She also discussed the site characterization project office and contractors under the project office. Ms. Sherwin stated that ONWI's contract will be up in 1987.

Mr. Murphy discussed SWEC's plan to describe the geologic system in terms of hydrogeologic considerations. He showed a slide depicting a section from Guadalupe to Parmer Counties. This section breaks the Wolfcamp and Pennsylvanian systems into hydrogeologic units.

Mr. Lamb (SWEC) stated that they are completing some gas permeability tests. He stated that the work should be completed this fall. They (SWEC) are looking at velocities, salt indices, and correlations between core and geophysical logs. He noted that they are trying to use resistivity to identify fractured zones (report T-43 ?). He stated that they are trying to correlate porosity to geophysical logs.

Dr. Gustavson (TBEG) discussed the current status of work undertaken by the Texas Bureau of Economic Geology. Current and soon-to-be-completed studies have looked at paleoclimate, plant remains, paleomagnetics, and evaluations of lacustrine deposits. He noted that they also are investigating interior dissolution rates, and the use of geophysical logs and core data to extrapolate via these logs to other geologic units. They are looking for faults that can be determined based on lithologic map sections rather than on just a couple of isolated pieces of data from wells. They do not plan to integrate this work with fracture studies. He noted that they are looking at geomorphic evidence for Tierra Blanca Creek which is south of the Deaf Smith site. Dr. Gustavson stated that the Black Water Formation is still being accummulated above the Ogallala Formation. He stated that there is a volcanic ash deposit near the bottom of the Black Water Draw Formation which has been age dated at approximately

1.4 million years. He noted also that the Black Water Draw Formation is essentially unsaturated: the unit is up to 100 ft thick.

Dr. Kreitler discussed the status of the hydrogeologic work. He updated the status based on figures used in the May 1984 workshop held at Columbus, Ohio. Dr. Kreitler stated that the data files are available for public dissemination: however, the draft reports which have not been reviewed are not subject to public review. Dr. Kreitler discussed the status of a varying number of reports. He stated that the areal modeling study of the Wolfcamp and Deep Basin system is currently under review at DOE. A steady state cross sectional model is under review at the Bureau of Economic Geology. A hypothetical fracture flow model through the evaporite section is now at the Bureau after being reviewed by DOE. A report describing the hydrologic characteristics of the Ogallala Formation is on his desk at this time. This report discusses travel times, interconnection to deeper units, and discharge from the Ogallala. A report which reviews the hydrology of the Dockum is currently under review at the Bureau. A topical report on a deep basin brine aquifer is at the Bureau at this time. A report detailing the geochemistry of the Wolfcamp and anomalous isotopic compositions is ongoing. A report describing the distribution of permeability also is ongoing at this time. A report detailing the clay mineralogy in the Palo Duro Basin soon will be sent to DOE. A report describing the geochemistry of the San Andres halites, mainly bromide chemistry, is being revised at the Bureau after being reviewed by DOE. The report describing the geochemistry of the deep brines should be released this fall. A report describing the hydrogeology of the San Andres is at DOE at this time. This report has a very limited data base: the report was prepared by Alan Dutton (TBEG). A report has been published in Water Resources Research describing the pressure-depth relationships in the Palo Duro Basin. Several well completion reports have been completed and an annual report for 1983 is being reviewed at the Bureau based on DOE comments. The 1984 annual report is under review at the Bureau at this time. Dr. Kreitler noted that the open-file report series will be phased out. The open-file reports will be replaced with contract reports in the future.

Dr. Trapp (NRC) questioned Dr. Kreitler concerning the status of the aeromagnetic map that the Bureau is preparing for the Palo Duro Basin. A Bureau representative noted that the State of Texas will issue a 1:750,000 ratio map of Texas based on data that Bendix had accummulated. Bendix ran out of money for the project and Texas is completing the project. The release of the aeromagnetic data is not related directly to the DOE effort.

The NRC group reconvened at 7:30 a.m. on August 8 to discuss

impressions of the information received and evaluated during this workshop. Our comments were prepared, discussed, and submitted to you at that time.

Sincerely,

Gerry Winter

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NRC Core Workshop
August 5-8, 1985
Austin, Texas

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