COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

GEOPHYSICAL TYPE LOGS

ECCV SLFH-3
49395-F
Sec 15 ,TWP 5s, RGE 66W
Elev: KB 5,920 ft MSL
TD: 2,534
SECTION E-E'

BAUGHMAN
05-005-06613
Sec 6 ,TWP 5S, RGE 62W
Elev: KB 5,575 ft MSL
TD: 7,606
SECTION S E-E' & N-N'

CASTLE PINES
USGS WELL
(44' NORTH OF
CASTLE PINES CORE)
Sec 9 ,TWP 7s, RGE 67W
Elev: KB 6,606 ft MSL
TD: 2,439
SECTION L-L'

TANIN NO. 1
05-039-06103
Sec 1 ,TWP 9S, RGE 65W
Elev: KB 6,779 ft MSL
TD: 9,043
SECTION H-H'

EHNANN 14-23
05-039-06018
Sec 23 ,TWP 7S, RGE 61W
Elev: KB 6,167 ft MSL
TD: 7,370
SECTION S G-G' & O-O'

#1 GREENLAND CATTLE
05-035-05000
Sec 17 ,TWP 10S, RGE 66W
Elev: KB 7,172 ft MSL
TD: 9,833
SECTION L-L'

PAINT BRUSH HILLS LFH
55192-F
Sec 25 ,TWP 12s, RGE 65W
Elev: GR 7,260 ft MSL
TD: 2,573
SECTION J-J'

#1 DZUROVCHIN
05-039-06116
Sec 19 ,TWP 10S, RGE 61W
Elev: KB 6,304 ft MSL
TD: 7,194
SECTION I-I'

IDENTIFICATION OF SEDIMENTARY LITHOFACIES

Sedimentary facies in the subsurface are identified by interpreting geophysical logs. Typical log suites in the Denver Basin consist of resistivity, spontaneous potential (SP), and natural gamma ray logs. Occasionally, sonic, density, and neutron logs are available. Where available in the records, descriptive geologic logs prepared by observation of drill cuttings or core samples can be compared to geophysical logs. The following table lists the sedimentary facies and the characteristic geophysical log responses used for their identification:

Litho-facies	Geophysical Log	Log Response
Sandstone/siltstone	Resistivity	High resistivity values, > 8 ohm-meters
	Resistance	High resistance, > 25 ohms
	Spontaneous Potential	Curve deflection
	Gamma ray	Low gamma ray emissions in quartz sands; Can be ambiguous in arkosic sands with high potassium feldspar content
Shale/Mudstone	Resistivity	Low resistivity, < 8 ohm-meters
	Resistance	Low resistance, < 25 ohms
	Spontaneous Potential	Baseline track
	Gamma ray	High gamma ray emissions

Low rank coal, or lignite, is present throughout the terrestrial deposits of the Denver Basin (Kirkham and Ladwig, 1979). It is associated with overbank deposits of the Denver Basin Group and tends to occur as thin discontinuous bodies. Lignite is also almost always present at the base of the Laramie Formation in seams that can be laterally continuous over large areas. Lignite is not annotated in the fifteen cross-sections of this publication because individual seams tend to be thin and discontinuous. Differentiation from sandstone is also difficult without descriptive sample logs or density logs, where coal is indicated by low bulk density values.

RECOGNITION OF GEOLOGIC UNITS AND SELECTION OF GEOLOGIC CONTACTS

Each of the geologic units can be recognized by characteristic patterns in the geophysical logs. Boundaries separating the units are recognized by distinct changes with depth in the patterns that can be traced from well to well. These boundaries can be easily recognized on many geophysical logs and in certain geographic locations in the basin. However, in many logs, and in other regions of the basin, the boundaries are less distinct and identification can be ambiguous. In these other regions, correlations of the litho-facies and identification of boundaries becomes more subjective often requiring iterative steps.

Pierre Shale: The Pierre Shale is easily recognized by very low resistivity values and little deflection in the resistivity curve and SP curve.

Fox Hills Sandstone: Sand content and grain size in the shoreline-deposited Fox Hills Sandstone bodies tend to increase upward resulting in an upward increase in resistivity. A "typical" Fox Hills resistivity curve displays a tapered shape with the highest values at the top responding to the coarsening upward grain size. The SP curve often mirrors the resistivity curve. Multiple "typical" Fox Hills sand bodies can be found stacked on top of each other separated by layers of shale. Locally, the "typical" upward increasing resistivity log trace may be absent and are replaced by blockier curve shapes. Rarely sand content is low, clay and silt content high, and the resistivity remains subdued. These lateral deviations in the more typical log trace may represent areas along the shoreline where the beach was interrupted by delta distributary channels or tidal channels.

- **Pierre Shale-Fox Hills Sandstone Contact:** This contact is transitional and is not delineated on the cross-sections. It is further complicated where multiple Fox Hills sand bodies stack.

Laramie Formation: Fine-grained siltstone and shale dominate the non-marine Laramie formation and resistivity values in the geophysical logs tend to be low and SP deflections minimal. Sand bodies formed by streams approaching the shoreline are common but tend to be laterally discontinuous and resistivity curves have a blocky shape in contrast to the tapered upward shape of the underlying Fox Hills sand bodies. Sand and silt are more common in the lower part of the Laramie Formation. Locally, basal Laramie Formation sand lenses can be quite thick and laterally continuous. Low rank coal, or lignite, is also common in the lower part of the Laramie Formation. Resistivity of the coals can be very high and "spiky" and density low. Sand and silt content generally decrease in the upper part of the Laramie Formation and, in response, the resistivity curve tends to decrease to a smooth trace.

- **Fox Hills Sandstone-Laramie Formation Contact:** The contact between the Laramie Formation and Fox Hills Sandstone is generally placed at the top of the uppermost massive sandstone body. On the resistivity logs, this is in the middle of the curve inflection. In some locations the typical coarsening upward Fox Hills Sandstone bodies are subdued or absent. In other locations, basal Laramie Formation sand lenses can overwhelm the Fox Hills sand bodies. Where these conditions occur, a definitive pick for the contact between the Fox Hills Sandstone and the Laramie Formation can be difficult. Correlation is made by iterative comparisons with nearby geophysical logs. Density logs are useful for identifying this contact by delineating low density coal in the Laramie Formation.

Denver Basin Group D1 Sequence: Geophysical log characteristics of the Denver Basin Group D1 Sequence are quite variable. Heterogeneity of the sedimentary package varies with proximity to the local mountain source rock and stratigraphic depth. Coarse-grained arkosic alluvial fan deposits are expressed in the geophysical logs as very high resistivity accompanied by sharp deflections in the SP curve. Layering is evident in the logs. Individual layer thicknesses vary and typical curve shapes tend to be blocky. Coarse-grained layers predominate close to the mountain front where geophysical log characteristics contrast sharply with the underlying Laramie Formation.

To the east, away from the mountain source, the high resistivity layers give way to more low resistivity, finer-grained overbank deposits. Higher resistivity layers are not as frequent, can be separated by thicker layers of low resistivity overbank deposits, and can be difficult to correlate laterally. Thickness of individual sand bodies varies and curve shapes tend to be blocky. Many sand body responses display a tapered shape with resistivity values gradually decreasing upward. This shape is interpreted to reflect fining-upward of grain size in the sand bodies typical of point-bar deposits derived from meandering streams. SP curves often mirror the resistivity trace. In areas distal from the sediment sources the geophysical log characteristics of the D1 Sequence become similar to those of the underlying Laramie Formation.

In the southern part of the basin the clastic material at the base is andesitic in composition. Weathering has rendered much of the andesitic material in this deposit to clay which displays low resistivity values and suppressed SP deflections. It resembles the underlying Laramie Formation in the geophysical logs and differentiation is difficult.

- **Laramie Formation-Denver Basin Group D1 Contact:** This contact is typically placed near the base of the high-resistivity clastic alluvial fan deposits where well developed. This distinctive upward transition to higher resistivity is present at most locations on the west side of the basin but becomes less defined further to the east. A subtle resistivity "kick" below the high-resistivity alluvial fan deposits is interpreted to be a basal conglomeratic layer. In the cross-sections the contact between the D1 Sequence and the Laramie Formation is placed at the base of this subtle inflection in the resistivity curve. If not present, the contact has been placed at the base of the higher resistivity arkosic alluvial fan deposits.

  The high resistivity fluvial deposits decrease in thickness and frequency away from the mountain front. Because of this, the basal contact is not as distinct further to the east. The contact is also not distinct at the southwestern edge of the basin where weathered andesitic material is present below the arkose. In these areas selection of the contact often requires iterative comparisons with nearby logs.

Intermediate Picks: Intermediate picks within the sequence facilitate correlation across the basin. These intermediate picks follow the bases of intervals where coarser-grained layers and lenses appear to be more frequent across the basin. These picks may resent the start of periods marked by more robust fan development.

- **Intermediate Pick D1i:** This pick is subtle and is not well defined on the west side of the basin where coarser-grained facies prevail. It becomes more easily recognized distally in the basin and proved to be a useful tool for correlations to the east.
- **Intermediate Pick D1ii:** This second intermediate pick depicted in the cross-sections marks the base of a thick upper section of the D1 Sequence where high resistivity sand bodies are more likely to be found across much of the basin. On the west side of the basin the interval appears to represent a notable period of robust fan development.

Denver Basin Group D2 Sequence: In many ways, geophysical log characteristics of the Denver Basin Group D2 Sequence resemble those of the underlying D1 Sequence. However, high resistivity coarse-grained deposits are more abundant in the D2 Sequence and extend further east into the basin, suggesting more robust alluvial fan development. On the west side of the basin, close to the source, multiple beds of high resistivity coarse-grained arkose overlap to form a nearly massive accumulation. To the east, away from the source, lower resistivity finer-grained overbank deposits become more common. Layering is evident in the logs, individual layer thicknesses are variable, and typical curve shapes tend to be blocky.

- **Denver Basin Group D1-D2 Contact:** This contact is evident in the subsurface as a transition from low resistivity, fine-grained sediments at the top of the D1 Sequence to higher resistivity, coarser-grained arkosic sediments in the D2 Sequence. To the east, away from the source, this transition becomes less distinct in the logs. Where this happens, correlation is aided by well-to-well comparisons. At many locations this contact follows a laterally continuous interval of reddish paleosols exposed at the surface. These paleosols are believed to have formed in the early Eocene, and therefore mark the base of the younger D2 sequence. Recognition of the paleosol interval in standard geophysical logs is subjective in the absence of descriptive sample logs or cores. The boundary is not made on the paleosol interval, but rather on the contrast in resistivity.

  Intermediate Pick D2i: In the central and eastern portions of the basin the high resistivity beds of arkose are more common in the upper part of the D2 Sequence. Low resistivity mudstones become more prevalent away from the source in the lower part of the sequence. Although this transition appears to be gradational it is a notable change that can be traced from well to well away from the source

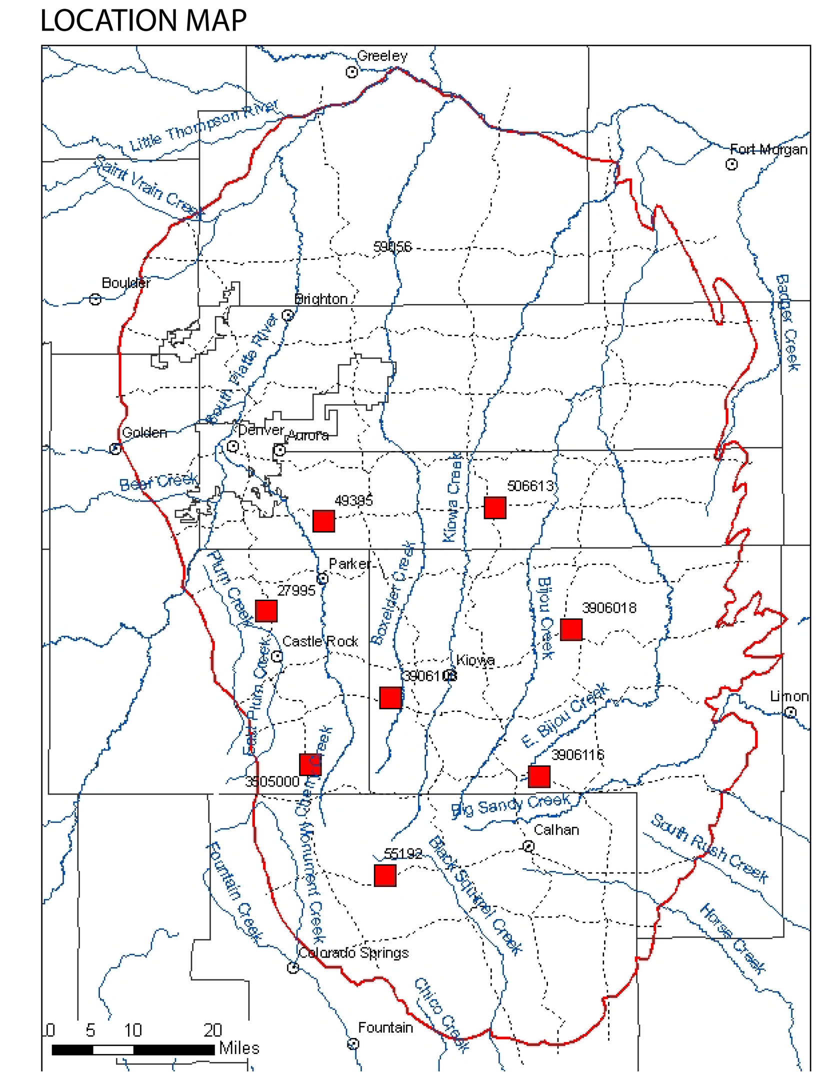
Younger Tertiary Rocks: The late Eocene rocks include the Larkspur Conglomerate, Wall Mountain Tuff, and Castle Rock Conglomerate and are depicted as one unit in the cross-sections. These deposits have limited extent and the number of boreholes with geophysical logs that cover them is limited. Geophysical log characteristics closely resemble those of the underlying Denver Basin Group D2 Sequence rendering differentiation subjective.

- **Denver Basin Group D2-Younger Tertiary Rocks Contact:** This contact is a regional unconformity representing a period of extensive erosion following Laramide synorogenic deposition. Contacts shown on the cross-sections are based primarily on surface geologic mapping projected into the subsurface.

Quaternary Cover: Quaternary cover in the Denver Basin includes alluvial deposits associated with modern-day streams and rivers combined with expanses of eolian deposits. Geophysical log coverage through these surficial deposits is limited. Where there is coverage, the unconsolidated coarse grained alluvial deposits tend to have very high resistivity values. Finer-grained overbank deposits and soils tend to have lower resistivity values.

- **Base of Quaternary Cover:** In geophysical logs this boundary is picked as the base of very high-resistivity intervals just below ground surface. Elsewhere, the boundary is based on descriptions provided in the geologic maps, surface casing setting depths, descriptive geologic logs in the DWR permit files, or published base of alluvium elevation maps (CWCB, 2005).

LOCATION MAP



CROSS-SECTIONS OF THE FRESH-WATER BEARING STRATA OF THE DENVER BASIN BETWEEN GREELEY AND COLORADO SPRINGS, COLORADO

By Peter E. Barkmann, Marieke Dechesne, Mary Ellen Wickham, Jill Carlson, and Scott Formolo
2011

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