An Evaluation of Carbon Dioxide Sequestration Potential in Mohawk Basin, Gila River Trough, Southwestern Arizona

Brian F. Gootee
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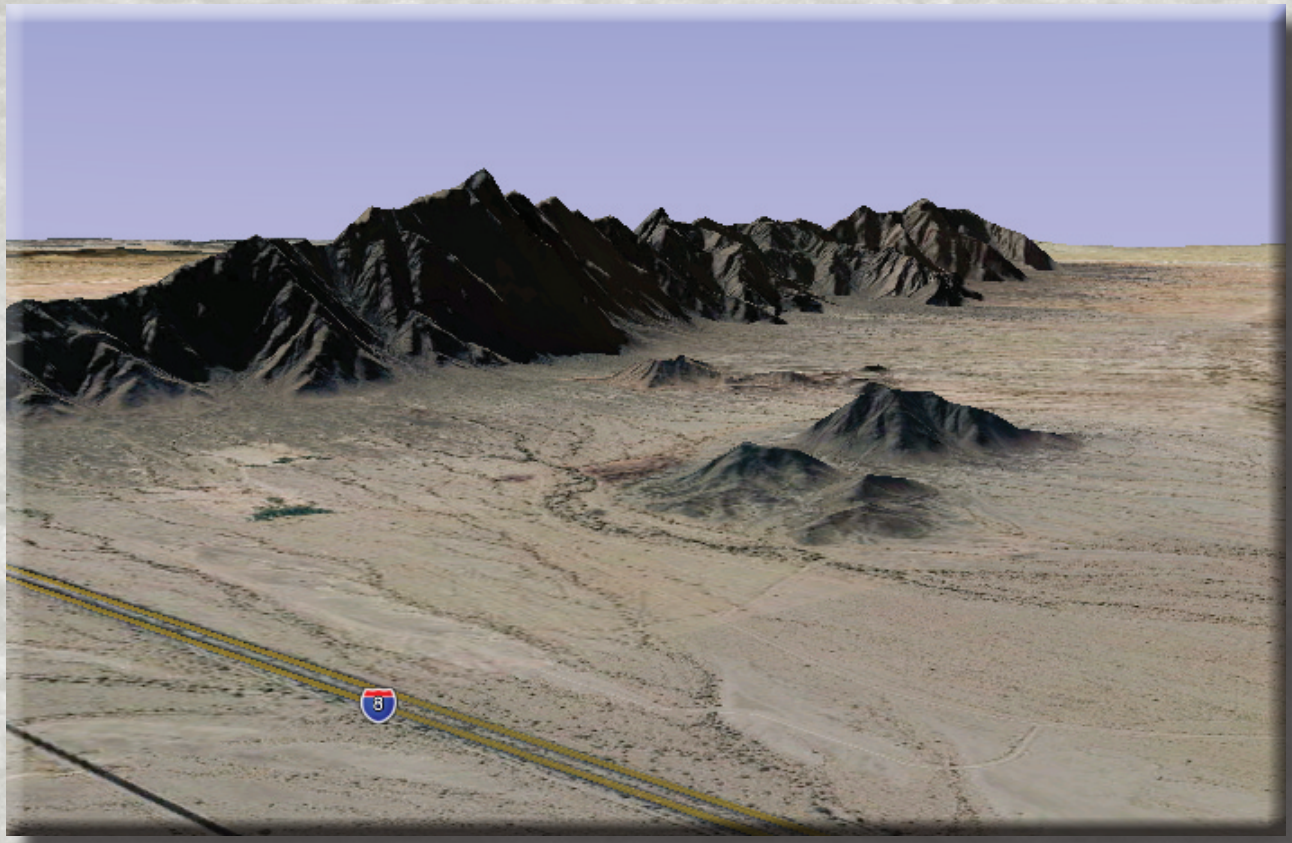

Mohawk Valley and west flank of the Mohawk Mountains of southwestern Arizona (Google Earth image).

OPEN-FILE REPORT OFR-13-02

March 2013

Arizona Geological Survey

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Arizona Geological Survey

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Manuscript approved for publication in March 2013
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Recommended Citation: Gootee, B.F., 2013, An Evaluation of Carbon Dioxide Sequestration Potential in Mohawk Basin, Gila River Trough, Southwestern Arizona. Arizona Geological Survey Open File Report, OFR-13-02, v 1.0, 8 p., 2 plates.

An Evaluation of Carbon Dioxide Sequestration Potential in Mohawk Basin, Gila River Trough, Southwestern Arizona

by

Brian F. Gootee

Arizona Geological Survey Open-File Report 13-02 v 1.0

March 2013

The Department of Energy (DOE), including its National Energy Technology Laboratory and West Coast Regional Carbon Sequestration Partnership (WESTCARB), have established national programs to evaluate the technical feasibility of long-term subsurface geologic storage of carbon dioxide (CO2) produced by industrial activity. The WESTCARB is a consortium of seven western U.S. States and one Canadian Province that is one of seven regional North American partnerships established to evaluate technical aspects of high-volume CO2 capture and sequestration. Collaborative WESTCARB research programs have included more than 90 public agencies, private companies, and non-profit organizations. The Arizona Geological Survey (AZGS) began work in 2010 on WESTCARB Phase III – Arizona Geological Characterization (California Energy Commission Agreement Number 500-10-024).

As part of WESTCARB Phase III, the AZGS is evaluating the potential for CO2 sequestration in geologic formations that are below a level of 800 meters (m) depth below land surface (bls). This evaluation is directed at porous and permeable geologic formations with impermeable sealing strata in Cenozoic sedimentary basins in the Basin and Range Province, and Paleozoic sedimentary formations in the Colorado Plateau. An initial screening of Cenozoic sedimentary basins with significant depth and volume below the 800 m bls level resulted in ten candidate basins from a total of 88 basins (Spencer, 2011). This report represents ongoing WESTCARB assessment of CO2 storage potential in the Mohawk basin, one of ten Cenozoic basins in Arizona identified during the preliminary evaluation, and is part of Tasks 2 and 3 of Arizona WESTCARB Phase III. Task 2 consists primarily of characterizing basin structure, stratigraphy, lithology, and the nature of seals or a cap rock. This task also includes determining the storage capacity of permeable sediments below 800 depth (Spencer, 2011). Task 3 is to determine if, and at what depth, saline groundwater approaches 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS), characterized in a separate study (Gootee and others, 2012). This concentration represents the threshold above which water is considered non-potable and unsuitable as drinking water (United States Environmental Protection Agency). Individual-basin studies such as this study are intended to provide estimates of the volume of permeable strata that are capped by impermeable strata (with an interface at depths greater than 800 m), and that are saturated with saline groundwater (>10,000 mg/L TDS).

Background. The Department of Energy (DOE), including its National Energy Technology Laboratory and West Coast Regional Carbon Sequestration Partnership (WESTCARB), have established national programs to evaluate the technical feasibility of long-term subsurface geologic storage of carbon dioxide (CO2) produced by industrial activity. The WESTCARB is a consortium of seven western U.S. States and one Canadian Province that is one of seven regional North American partnerships established to evaluate technical aspects of high-volume CO2 capture and sequestration. Collaborative WESTCARB research programs have included more than 90 public agencies, private companies, and non-profit organizations. The Arizona Geological Survey (AZGS) began work in 2010 on WESTCARB Phase III – Arizona Geological Characterization (California Energy Commission Agreement Number 500-10-024).

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The Mohawk basin is a northwest-trending Cenozoic basin in the southwestern portion of the Basin and Range tectonic province. The Mohawk basin is situated between the Mohawk Mountains to the east and the Muggins, Copper, Cabeza Prieta, and Sierra Pinta Mountains to the west. The Gila River flows through the northern portion of Mohawk valley, north of Interstate Highway 8 which passes through the town of Tacna near the western borders of the basin. The Mohawk basin's Cenozoic basin-fill sediments are estimated to be as much as 2,400 m (8,000 ft) thick (Oppenheimer and Sumner, 1980; Saltus and Jachens, 1995; Richard et al., 2007) (Plate 1) and it is one of ten Cenozoic basins in Arizona identified as having potential for carbon dioxide (CO2) sequestration (Spencer, 2011) with an estimated total sediment volume of 1,288 cubic kilometers (km3) (309 cubic miles (mi3)). Approximately 519 km3 (125 mi3) of basin-filling strata are estimated to lie below a depth of 800 m (2,625 ft).

Due to the absence of deep wells, very little is known about the Mohawk basin's subsurface conditions. The deepest well in the basin penetrates 288 m (945 ft) below land surface (bls). Lithologic data are available for only four wells that were completed deeper than 236 m (775 ft). These wells are listed in Appendix A and recorded lithologic intervals are tabulated in Appendix B. Well locations are plotted on Plate 1 and used in geologic cross-sections AA' and BB' in Plate 2. Due to the lack of sufficient subsurface data, the geology of neighboring basins and regional geology were used as proxies to illustrate the geology of the Mohawk basin (Eberly and Stanley, 1978; Menges and Pearthree, 1989; Spencer and Reynolds, 1989; Spencer and others, 1995, 1996).

Mid-Tertiary (Oligocene to middle Miocene) sedimentary and volcanic rocks on the northern flanks of Copper and Mohawk Mountains and in the Muggins Mountains (Pridmore and Craig, 1982; Mueller et al., 1982; Smith et al., 1989; Plate 1) almost certainly underlie younger basin-filling strata in the Mohawk basin (Plate 2). The Mohawk detachment fault, exposed in the northern Mohawk Mountains, is a low angle normal fault that juxtaposed the lower-plate Precambrian gneiss with the upper-plate Laramide granites and depositionally-overlying mid-Tertiary conglomerate and sedimentary breccia derived from the granites (Mueller et al., 1982). Spencer and Reynolds (1989) suggest that slip along the detachment fault has between 5 and 15 km displacement of the upper plate to the northeast (Plate 2). In the Baker Peaks-Copper Mountains-Wellton Hills area, a detachment fault juxtaposes lower-plate gneiss with upper-plate mid-Tertiary clastic rocks (Pridmore and Craig, 1982). The upper-plate clastic sequence, dipping to the southwest at angles from moderate to steep due to fault-block tilting, is interpreted to have been deposited during movement on the detachment fault. Northeast-dipping normal faults, thought to be related to detachment faulting, cut the strata. Deposition of the mid-Tertiary sequence may have begun during initial extension ~25 million years ago (Ma) and continued until about 15 Ma (Spencer and others, 1995). Thickness of the mid-Tertiary sequence may be as much as 1,200 m (3,900 ft) in the region. Younger normal faulting that produced the modern basin and range topography of the region probably began in the late Miocene. However, this timing is very poorly constrained by geologic data (e.g., Menges and Pearthree, 1989). An erosional surface and angular unconformity likely separates the mid-Tertiary sequence from overlying, early basin-fill deposits.

Gravity data suggest that Mohawk Valley may be a half-graben, with a steep gravity gradient on the northeast side of the basin that reflects a buried normal fault and deep basin sediments, and a more gentle gravity gradient on the southwest side that reflects the gently northeast-tilted floor of the basin. If this half-graben basin was hydrologically closed during basin genesis, then evaporites such as halite and gypsum may have been deposited in the basin axis; however, no evaporites were identified from a seismic survey along the Gila River (Eberly and Stanley, 1978).

Shallow wells in the Mohawk basin encountered Gila River alluvium and basin-fill clastic deposits. Towards the basin center, clay and fine sand alternate throughout the upper 245 m (800 ft). In 35-well 15751, a sticky blue clay was reported between 245 and 288 m (800 and 945 ft) and appears to be continuous towards the basin center. Nearby Cenozoic basins (King, San Cristobal and Growler) are untested in the gravity lows, but shallow wells in those basins are reported to have encountered gypsiferous sediments (Rauzi, 2001). In Oil and Gas (OG) well 14-11 in San Cristobal basin (Plate 1), sticky red clay and sand was encountered between 730 m (2,400 ft) and at total depth of 802 m (2,630 ft). Oozing black mud was reported in the lowest 9 m (30 ft). Fine-grained sediment with gypsum, white talc, quartz and soapstone were reported between 365 and 488 m (1,200 and 1,600 ft). Groundwater salinity in the Mohawk basin and other nearby Cenozoic basins is essentially unknown. Salinity of shallow groundwater in Mohawk basin is brackish and saline, likely related to shallow, downward-percolating groundwater recharged from agricultural irrigation (Gootee and others, 2012; El-Ashry, 1980).

The dearth of subsurface data from Mohawk basin precludes accurate evaluation of carbon-sequestration potential. Evaporite deposits favorable for sealing conditions may be present, especially near the northeast margin of the basin. Permeable strata may also be present in lower basin-fill strata, and/or in underlying tilted mid-Tertiary clastic rocks, if present. However, accurate evaluation of CO2 sequestration potential of Mohawk basin will require further investigation through drilling and seismic surveys.

List of Attachments

Appendix A – Well Inventory
Appendix B – Borehole Log Data
Plate 1 – Location map of the Mohawk basin
Plate 2 – Geologic cross-sections AA' and BB'

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Appendix A

Wells below 775 ft (235 m) used for evaluation of CO_2 storage in the Mohawk basin

Well Type	Label	Well ID	Elevation (m)	Elevation (ft)	UTM-Easting (NAD83, 12N)	UTM-Northing (NAD83, 12N)	Well Depth (m)	Well Depth (ft)	Log Type
35	35-15751	15751	107	351	227,942	3,620,966	288	945	Drillers
35	35-15752	15752	119	392	224,851	3,619,418	236	775	Drillers
35	35-15916	15916	127	418	221,620	3,618,882	279	917	Drillers
55	55-502495	502495	100	328	229,371	3,621,544	247	809	Drillers

ADWR Well Type	Well ID	Elev. (m)	Elev. (ft)	From Depth (ft)	To Depth (ft)	Thick-ness (ft)	From Depth (m)	To Depth (m)	Top Elev. (m)	Bottom Elev. (m)	HGUID*	HGU Code*	Lithology
35	15751	107	351	0	2	2	0	1	107	106	PC	2	topsoil
35	15751	107	351	2	15	13	1	5	106	102	PC	2	caliche and sand
35	15751	107	351	15	40	25	5	12	102	95	PF	3	sandy clay
35	15751	107	351	40	120	80	12	37	95	70	CL	4	clay
35	15751	107	351	120	170	50	37	52	70	55	CL	4	silty clay
35	15751	107	351	170	172	2	52	52	55	55	PC	2	quick sand
35	15751	107	351	172	205	33	52	62	55	44	PF	3	silty clay
35	15751	107	351	205	207	2	62	63	44	44	PF	3	silty sand
35	15751	107	351	207	222	15	63	68	44	39	PF	3	silty clay
35	15751	107	351	222	230	8	68	70	39	37	PC	2	fine sand
35	15751	107	351	230	240	10	70	73	37	34	CL	4	clay
35	15751	107	351	240	290	50	73	88	34	19	PF	3	silty clay
35	15751	107	351	290	292	2	88	89	19	18	PC	2	quick sand
35	15751	107	351	292	312	20	89	95	18	12	PF	3	silty clay
35	15751	107	351	312	314	2	95	96	12	11	PC	2	silty sand
35	15751	107	351	314	320	6	96	98	11	9	PF	3	silty clay
35	15751	107	351	320	340	20	98	104	9	3	CL	4	sticky clay
35	15751	107	351	340	370	30	104	113	3	-6	PF	3	silty clay and sand
35	15751	107	351	370	385	15	113	117	-6	-10	CL	4	clay
35	15751	107	351	385	387	2	117	118	-10	-11	PC	2	sitly sand
35	15751	107	351	387	420	33	118	128	-11	-21	CL	4	clay
35	15751	107	351	420	430	10	128	131	-21	-24	PC	2	fine powdery sand
35	15751	107	351	430	440	10	131	134	-24	-27	BC	5	blue clay
35	15751	107	351	440	450	10	134	137	-27	-30	CL	4	clay
35	15751	107	351	450	468	18	137	143	-30	-36	CL	4	sticky clay
35	15751	107	351	468	480	12	143	146	-36	-39	PC	2	fine powdery sand
35	15751	107	351	480	485	5	146	148	-39	-41	CL	4	caving clay
35	15751	107	351	485	502	17	148	153	-41	-46	CL	4	clay
35	15751	107	351	502	512	10	153	156	-46	-49	PC	2	fine sand (no water)
35	15751	107	351	512	540	28	156	165	-49	-58	CL	4	sticky clay
35	15751	107	351	540	570	30	165	174	-58	-67	PC	2	fine sand
35	15751	107	351	570	574	4	174	175	-67	-68	CL	4	clay
35	15751	107	351	574	605	31	175	184	-68	-77	CL	4	tough red clay
35	15751	107	351	605	620	15	184	189	-77	-82	CL	4	red clay with sand stone streaks
35	15751	107	351	620	632	12	189	193	-82	-86	PC	2	fine sand
35	15751	107	351	632	642	10	193	196	-86	-89	CL	4	red sticky clay
35	15751	107	351	642	645	3	196	197	-89	-90	PC	2	fine sand
35	15751	107	351	645	650	5	197	198	-90	-91	CL	4	red clay
35	15751	107	351	650	655	5	198	200	-91	-93	CL	4	clay
35	15751	107	351	655	680	25	200	207	-93	-100	PC	2	fine sand
35	15751	107	351	680	690	10	207	210	-100	-103	PF	3	sandy clay
35	15751	107	351	690	710	20	210	216	-103	-109	PC	2	fine sand
35	15751	107	351	710	730	20	216	222	-109	-116	CL	4	clay
35	15751	107	351	730	755	25	222	230	-116	-123	PF	3	sandy clay
35	15751	107	351	755	765	10	230	233	-123	-126	PC	2	fine sand
35	15751	107	351	765	810	45	233	247	-126	-140	PF	3	sandy clay
35	15751	107	351	810	825	15	247	251	-140	-144	CL	4	clay
35	15751	107	351	825	830	5	251	253	-144	-146	PC	2	fine sand
35	15751	107	351	830	880	50	253	268	-146	-161	BC	5	blue sticky clay
35	15751	107	351	880	890	10	268	271	-161	-164	BC	5	blue sandy clay
35	15751	107	351	890	925	35	271	282	-164	-175	BC	5	blue sticky clay with streaks of sand
35	15751	107	351	925	932	7	282	284	-175	-177	BC	5	blue clay
35	15751	107	351	932	940	8	284	286	-177	-180	PC	2	fine sand

ADWR Well Type	Well ID	Elev. (m)	Elev. (ft)	From Depth (ft)	To Depth (ft)	Thick-ness (ft)	From Depth (m)	To Depth (m)	Top Elev. (m)	Bottom Elev. (m)	HGUID*	HGU Code*	Lithology
35	15751	107	351	940	945	5	286	288	-180	-181	BC	5	blue clay
35	15752	119	392	0	8	8	0	2	119	117	PF	3	alluvium -- sandy loam to reddish brown clay
35	15752	119	392	8	25	17	2	8	117	112	PC	2	soft caliche
35	15752	119	392	25	45	20	8	14	112	106	PF	3	brown clay intermixed with light gravel
35	15752	119	392	45	52	7	14	16	106	104	PC	2	hard cemented sand
35	15752	119	392	52	65	13	16	20	104	100	PF	3	sandy clays
35	15752	119	392	65	68	3	20	21	100	99	PC	2	hard shelf, cemented sand
35	15752	119	392	68	78	10	21	24	99	96	CL	4	consolidated brown clay
35	15752	119	392	78	96	18	24	29	96	90	PF	3	brown sandy clay
35	15752	119	392	96	98	2	29	30	90	90	PC	2	shelf, hard cemented sand
35	15752	119	392	98	132	34	30	40	90	79	CL	4	hard brown clay
35	15752	119	392	132	137	5	40	42	79	78	PC	2	hard cemented sand
35	15752	119	392	137	165	28	42	50	78	69	PF	3	clay with intermitten layers of small gravel
35	15752	119	392	165	172	7	50	52	69	67	PC	2	fine sands -- first water evidence
35	15752	119	392	172	195	23	52	59	67	60	PC	2	clay with intermitten layers of fine sand
35	15752	119	392	195	202	7	59	62	60	58	CL	4	hard brown clay
35	15752	119	392	202	247	45	62	75	58	44	PF	3	sandy clays with intermitten layers of sandstone
35	15752	119	392	247	254	7	75	77	44	42	CL	4	hard clay
35	15752	119	392	254	327	73	77	100	42	20	PF	3	sandy clays with intermitten sandstone shelves
35	15752	119	392	327	332	5	100	101	20	18	CL	4	consolidated clay
35	15752	119	392	332	337	5	101	103	18	17	PC	2	fine sands -- water percolating
35	15752	119	392	337	366	29	103	112	17	8	PF	3	sandy clays
35	15752	119	392	366	386	20	112	118	8	2	CL	4	hard, dry clay
35	15752	119	392	386	400	14	118	122	2	-2	PC	2	hard sand stone
35	15752	119	392	400	413	13	122	126	-2	-6	PF	3	fine sand and clays -- water percolating
35	15752	119	392	413	420	7	126	128	-6	-9	PC	2	sand stone
35	15752	119	392	420	426	6	128	130	-9	-10	CL	4	hard clay
35	15752	119	392	426	460	34	130	140	-10	-21	PC	2	fine sand, sand clays -- occasional layers coarse sands
35	15752	119	392	460	465	5	140	142	-21	-22	PC	2	soft sandstone
35	15752	119	392	465	475	10	142	145	-22	-25	BC	5	red and blue clay
35	15752	119	392	475	480	5	145	146	-25	-27	CL	4	red clays
35	15752	119	392	480	498	18	146	152	-27	-32	PF	3	fine sand and clays
35	15752	119	392	498	502	4	152	153	-32	-34	CL	4	very hard clay
35	15752	119	392	502	528	26	153	161	-34	-41	PF	3	sandy clays
35	15752	119	392	528	530	2	161	162	-41	-42	CL	4	tough, leathery clay
35	15752	119	392	530	582	52	162	177	-42	-58	PC	2	soft sandstone permeated with fine sands - good water
35	15752	119	392	582	613	31	177	187	-58	-67	PF	3	sands and clay -- water
35	15752	119	392	613	616	3	187	188	-67	-68	PC	2	hard sandstone
35	15752	119	392	616	638	22	188	194	-68	-75	PF	3	sands and clay -- water
35	15752	119	392	638	645	7	194	197	-75	-77	CL	4	tough clay
35	15752	119	392	645	706	61	197	215	-77	-96	PC	2	hard sandstone with layers of fine sand -- good water
35	15752	119	392	706	718	12	215	219	-96	-99	PC	2	very hard sandstone
35	15752	119	392	718	765	47	219	233	-99	-114	PC	2	water sands laid in soft sandstone
35	15752	119	392	765	775	10	233	236	-114	-117	PC	2	hard sandstone
35	15916	127	418	0	3	3	0	1	127	126	PC	2	soil
35	15916	127	418	3	15	12	1	5	126	123	C	1	volcanic sand and gravel
35	15916	127	418	15	40	25	5	12	123	115	CL	4	clay
35	15916	127	418	40	180	140	12	55	115	73	PF	3	sandy clay
35	15916	127	418	180	181	1	55	55	73	72	PC	2	sand (first water)

ADWR Well Type	Well ID	Elev. (m)	Elev. (ft)	From Depth (ft)	To Depth (ft)	Thick-ness (ft)	From Depth (m)	To Depth (m)	Top Elev. (m)	Bottom Elev. (m)	HGUID*	HGU Code*	Lithology
35	15916	127	418	181	240	59	55	73	72	54	PF	3	clay with layers of sand
35	15916	127	418	240	250	10	73	76	54	51	CL	4	clay
35	15916	127	418	250	300	50	76	91	51	36	PF	3	sandy clay and gravel
35	15916	127	418	300	310	10	91	94	36	33	C	1	coarse sand and pea gravel
35	15916	127	418	310	365	55	94	111	33	16	PC	2	sand gravel and clay in layers
35	15916	127	418	365	380	15	111	116	16	12	CL	4	sticky clay
35	15916	127	418	380	435	55	116	133	12	-5	PC	2	clay small gravel and coarse sand
35	15916	127	418	435	570	135	133	174	-5	-46	PC	2	coarse sand and clay
35	15916	127	418	570	620	50	174	189	-46	-62	PC	2	silty sandy clay and gravel
35	15916	127	418	620	625	5	189	190	-62	-63	PC	2	sand
35	15916	127	418	625	670	45	190	204	-63	-77	PC	2	firm sand
35	15916	127	418	670	725	55	204	221	-77	-94	PF	3	coarse sandy clay
35	15916	127	418	725	732	7	221	223	-94	-96	PC	2	coarse sand
35	15916	127	418	732	735	3	223	224	-96	-97	PC	2	granite or chert (very hard)
35	15916	127	418	735	765	30	224	233	-97	-106	PF	3	fine sand and clay
35	15916	127	418	765	860	95	233	262	-106	-135	PC	2	coarse sand and conglomerate and clay
35	15916	127	418	860	890	30	262	271	-135	-144	PC	2	coarse red sand
35	15916	127	418	890	900	10	271	274	-144	-147	C	1	clay and conglomerate
35	15916	127	418	900	907	7	274	276	-147	-149	PC	2	red sand
35	15916	127	418	907	917	10	276	279	-149	-152	C	1	brownish clay sand and conglomerate (very hard)
55	502495	100	328	0	5	5	0	2	100	98	PC	2	top soil
55	502495	100	328	5	18	13	2	5	98	94	PC	2	coarse brown sand
55	502495	100	328	18	26	8	5	8	94	92	CL	4	yellow clay
55	502495	100	328	26	48	22	8	15	92	85	PC	2	fine brown sand
55	502495	100	328	48	238	190	15	73	85	27	PF	3	brown sandy clay
55	502495	100	328	238	249	11	73	76	27	24	CL	4	brown clay (sticky)
55	502495	100	328	249	286	37	76	87	24	13	PC	2	soft brown sand stone
55	502495	100	328	286	291	5	87	89	13	11	C	1	brown clay and boulders
55	502495	100	328	291	327	36	89	100	11	0	PC	2	soft brown sand stone
55	502495	100	328	327	352	25	100	107	0	-7	C	1	brown sand stone with boulders and traces of brown clay
55	502495	100	328	352	488	136	107	149	-7	-49	PF	3	brown sandy clay
55	502495	100	328	488	705	217	149	215	-49	-115	PC	2	fine brown sand with streaks of brown clay
55	502495	100	328	705	714	9	215	218	-115	-118	PC	2	fine brown sand
55	502495	100	328	714	805	91	218	245	-118	-145	PC	2	fine light brown sand with traces of clay
55	502495	100	328	805	809	4	245	247	-145	-147	CL	4	brown sticky clay

*** Description**

HGUID	HGU Code	Description
C	1	Predominantly conglomeratic or gravelly sediment
PC	2	Predominantly coarse grained sediments (sand and gravel)
PF	3	Predominantlly fine grained sediments (silt and clay)
CL	4	Predominantly clay deposits
BC	5	Blue clay