Ohio Environmental Protection Agency

DIVISION OF DRINKING AND GROUND WATERS

UNDERGROUND INJECTION CONTROL PERMIT TO DRILL: CLASS I NON HAZARDOUS WELL

Ohio Permit No.: UIC 04-16-001-PTD-I

Date of Issuance:

Effective Date:

Date of Expiration:

Name of Applicant:	Buckeye Brine, LLC
Facility Location:	23986 Airport Rd. Coshocton, Ohio 43812
Mailing Address:	2360 Exposition Blvd, Suite 117 Austin, TX 78703
County:	Coshocton
Township:	Keene
Lot number:	Lot 4
Well Name:	Adams #4
Well Location:	40°18'3.79" N/ -81°50'57.51" W
Total Depth:	+/- 7,000' Total Vertical Depth to Rose Run (measured from Kelly Bushing (KB) height). Ground level elevation estimated at 760 feet (+/- 10 feet) above sea level.

The above named permittee is hereby issued a Permit to Drill for the above described underground injection well pursuant to Chapter 3745-34 of the Ohio Administrative Code. Issuance of this Permit to Drill does not constitute expressed or implied assurances that if constructed and/or modified in accordance with those specifications and/or information accompanying the permit application, the permittee will be granted an operating permit.

The permittee, its employees, subsidiaries, successors, contractors, and others acting in concert with the permittee are solely responsible to maintain control of the well at all times and will ensure at all times, the drilling and construction of the well will be protective of human health and the environment. This Permit to Drill is issued subject to the conditions provided in the permit and all applicable provisions: of Chapter 6111. of the Ohio Revised Code and the rules adopted thereunder; of Chapter 3745-34 of the Ohio Administrative Code; and of 40 C.F.R. Parts 124, 144, and 146 which are also hereby incorporated. Nothing in this Permit to Drill should be deemed to relieve the permittee of any obligations under applicable local, state, or federal laws. Where these incorporated provisions conflict with the expressed terms and conditions, the expressed terms and conditions shall control.

This permit and the authorization to drill shall expire at midnight, unless terminated, on the date of expiration indicated.

Anne M. Vogel, Director
Ohio Environmental Protection Agency

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PART I
GENERAL PERMIT CONDITIONS

A. EFFECT OF PERMIT

The permittee is authorized to engage in the construction of an underground injection well in accordance with the conditions of this permit. Notwithstanding any other provisions of this permit, the permittee authorized by this permit shall not construct, operate, maintain, convert, plug, abandon, or conduct any other activity in a manner that allows the movement of fluids into underground sources of drinking water (USDW). Any underground injection activity not specifically authorized in this permit is prohibited. Compliance with this permit during its term constitutes compliance for purposes of enforcement, with Sections 6111.043 and 6111.044 of the Ohio Revised Code (ORC). Such compliance does not constitute a defense to any action brought under ORC Sections 6109.31, 6109.32 or 6109.33 or any other common or statutory law other than ORC Sections 6111.043 and 6111.044. Issuance of this permit does not convey property rights of any sort or any exclusive privilege nor does it authorize any injury to persons or property, any invasion or other private rights, or any infringement of state or local law.

This permit does not relieve the permittee of its obligation to comply with any additional applicable regulations or requirements for any generating, handling, storage, treatment or disposal facilities. Such activities must receive separate authorization under applicable regulations.

B. PERMIT ACTIONS

1. Modification, Revocation, Reissuance and Termination. The Director may, for cause or upon request from the permittee, modify, revoke, and reissue, or terminate this permit in accordance with Ohio Administrative Code (OAC) Rules 3745-34-07, 3745-34-23, 3745-34-24, and 3745-34-26. Also, the permit is subject to OAC 3745-34-27(A). Changes in construction may be approved as minor modifications for cause as specified in OAC Rule 3745-34-25. The filing of a request for a permit modification, revocation and reissuance, or termination, or the notification of planned changes, or anticipated non-compliance on the part of the permittee does not stay the applicability or enforceability of any permit condition.

2. Transfer of Permits. This permit may be transferred to a new owner or operator only if it is modified or revoked and reissued pursuant to OAC 3745-34-22(A), 3745-34-23(B)(2), or 3745-34-25(D) as applicable.

C. DURATION OF PERMIT (OAC 3745-34-21(D)(1))

This Permit to Drill shall terminate within eighteen (18) months of the effective date if the permittee has not undertaken a continuing program of construction or has not entered into a binding contractual obligation to undertake and complete construction within a reasonable time.

D. SEVERABILITY

The provisions of this permit are severable, and if any provision of this permit or the application of any provision of this permit to any circumstance is held invalid, the application of such provision to any other circumstances and the remainder of this permit shall not be affected thereby.

E. CONFIDENTIALITY

In accordance with 40 CFR Part 2 and OAC Rule 3745-34-03, any information submitted to the Ohio EPA pursuant to this permit may be claimed as confidential by the submitter. Any such claim must be asserted at the time of submission by stamping the words “confidential business information” on each page containing such information. If no claim is made at the time of submission, Ohio EPA may make the information available to the public without further notice. If a claim is asserted, documentation for the claim must be tendered and the validity of the claim will be assessed in accordance with the procedures in OAC Rules 3745-34-03 and 3745-49-03. If the documentation for the claim of confidentiality is not received, the Ohio EPA may deny the claim without further inquiry. Claims of confidentiality for the following information will be denied:

1. The name and address of the permittee; and

2. Information which deals with the existence, absence or level of contaminants at the permitted facility.

F. DUTIES AND REQUIREMENTS

1. Duty to Comply. The permittee shall comply with all applicable UIC regulations and conditions of this permit, except to the extent and for the duration such non-compliance is authorized by an emergency permit issued in accordance with OAC Rule 3745-34-19. The permittee shall take all reasonable steps to minimize or correct any adverse impact on the environment resulting from implementation of or noncompliance with this permit. Any permit noncompliance constitutes a violation of ORC Chapter 6111 and is grounds for enforcement action, permit termination, revocation and reissuance, or modification. Such non-compliance may also be grounds for enforcement action under other applicable state and federal law.

2. Penalties for Violations of Permit Conditions. Any person who violates a permit requirement is subject to injunctive relief, civil penalties, fines, and/or other enforcement action under ORC Chapter 6111. Any person who knowingly or recklessly violates permit conditions may be subject to criminal prosecution.

3. Need to Halt or Reduce Activity Not a Defense. It shall not be a defense for a permittee in an enforcement action, that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit or any order issued by the Director or a court of appropriate jurisdiction.

4. Duty to Mitigate. The permittee shall take all reasonable steps to minimize or correct any adverse impact on the environment resulting from noncompliance with this permit. This may include accelerated or additional monitoring or testing or both. If such is performed,

the data collected shall be submitted to Ohio EPA in a written report within ninety (90) days of completion of all related activities.

5. Proper Operation and Maintenance. The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of the permit. "Proper operation and maintenance" includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of the permit.

6. Reporting Requirements

   a. Pursuant to OAC 3745-34-27(A)(1), changes in construction plans during construction may be approved by the Director as minor modifications (OAC Rule 3745-34-25). No such changes may be physically incorporated into construction of the well prior to approval of the modification by the Director.

   b. Written notice of any planned physical alterations to the well shall be given to Ohio EPA ten (10) days prior to commencement of any alteration. A shorter time period may be approved by the Director. Furthermore, the permittee shall provide justification for any planned physical alterations to the permitted well. Prior to implementation of any alteration, the permittee shall have written approval for the proposed alteration from Ohio EPA.

   c. The permittee shall report to the Director any non-compliance which may endanger human health or the environment. All available information shall be provided orally within twenty-four (24) hours from the time the permittee becomes aware of such noncompliance. The following events shall be reported orally within twenty-four (24) hours:

      i. Any monitoring or other information which indicates that any contaminant may cause an endangerment to an underground source of drinking water.
      ii. Any non-compliance with a permit condition, or malfunction of the drilling equipment, which may cause fluid migration into or between underground sources of drinking water.

   d. A written submission shall also be provided within five (5) working days from the time the permittee becomes aware of the circumstances of such non-compliance. The written submission shall contain the following:

      i. A complete description of the non-compliance and its cause; and
      ii. The time, date, and duration of the period of non-compliance; and
      iii. If the non-compliance has not been corrected, the anticipated time it is expected to continue; and
      iv. Identification and quantification (including sample results when available) of all substances released to the environment or involved in the incident or event; and
      v. A description of all remedial measures taken or to be taken; and
      vi. A description of the extent of contamination or damage to the environment; and
      vii. Any monitoring or other documentation available about the incident; and

viii. A description of the steps taken or planned to reduce or eliminate the possibility of recurrence of the non-compliance.

7. Injection. The permittee may not commence injection of waste into the well until final approval for a Permit to Operate has been issued by the Director of Ohio EPA. Any other injection required during well testing to acquire data or to perform a well stimulation is excluded from this stipulation but shall be conducted in accordance with a plan(s) approved, in advance, by Ohio EPA and will be subject to all other provisions of this permit.

8. Signatory Requirements. All applications, reports, or other information required to be submitted by this permit, requested by the Director or submitted to the Director, shall be signed and certified in accordance with OAC Rule 3745-34-17.

G. INSPECTION AND ENTRY

1. In accordance with OAC 3745-34-26(I) and 3745-34-55(F) the Ohio EPA shall have authority and access to witness or to inspect for compliance with this permit; all drilling, testing, logging, and construction of the well. The permittee shall submit a schedule of such activities in writing to Ohio EPA prior to commencement. The permittee shall notify Ohio EPA at a minimum of twenty-four (24) hours prior to any logging or well tests.

2. The permittee shall inform Ohio EPA of the progression and scheduling of drilling and testing daily until the well is completed, and the report submitted. A written driller's report, containing information specified in Part II (H)(3) of this permit shall be submitted daily, when drilling commences, in an electronic format until the well is completed. For the purpose of this permit to drill provision, daily is defined as occurring at least once every calendar day, until the well is completed.

H. ANALYSIS OF DATA

1. Field results from all well logging shall be submitted within ten (10) days of completion of the activity. A field log shall be made available the day of the logging at Ohio EPA's request.

2. The following results obtained during construction of the well, along with a technical appraisal of the results, shall be submitted to the Ohio EPA, in the form of a report or within an application for a Permit to Operate (five copies required), no later than sixty (60) days after the well drilling and testing is completed, including:

   a. All geophysical logs, well completion, mud log, well testing, core data, an as-built well schematic, and any other technical data; and,

   b. Results of injection and reservoir testing. These results are to include information on effective reservoir thickness, reservoir pressure build-up, and anticipated radial movement of the waste.

   c. The results of the testing in Part II (C)(5).

   d. A demonstration of fracture gradient, the fracture initiation, propagation, and closure pressures shall be submitted.

I. FINANCIAL RESPONSIBILITY (OAC Rule 3745-34-62)

1. Adequate financial assurance for the proposed well must be established and approved by Ohio EPA prior to the commencement of drilling. Cost estimates to cover closure and post-closure costs of the proposed well is included within Attachment D of this Permit to Drill.

2. The permittee shall notify Ohio EPA within ten (10) days of bankruptcy or insolvency (in any form) of the permittee or the entity providing financial assurance. In addition, notice shall be given within ten (10) days of event if any bonds, insurance or other security submitted under this paragraph lapse, are transferred, or are otherwise compromised.

3. The permittee is required to establish, maintain financial responsibility and resources to close, plug, and abandon the injection well. The obligation to maintain financial resources to close, plug, and abandon the well survives the termination of this permit.

4. During the operating life of the facility, the permittee shall keep on file at the facility a copy of the latest closure and post-closure cost estimates prepared in accordance with OAC Rules 3745-34-60 and 3745-34-61.

J. PLUGGING AND ABANDONMENT (OAC Rule 3745-34-36)

1. If plugging and abandonment of this well is required, then the well shall be plugged and abandoned in accordance with the plans found in Attachment D of this permit. The plan is subject to final approval by Ohio EPA. The requirement to maintain and implement the plugging and abandonment plan is enforceable until plugging and abandonment are completed in accordance with the plan.

2. The permittee at all times remains responsible for this well and any environmental impact caused by the drilling or use of the well, whether authorized or unauthorized, including after plugging and abandonment of the well.

3. In accordance with OAC rule 3745-34-60(B), the permittee shall notify the Director at least sixty (60) calendar days before the anticipated date of plugging and abandonment of the well, unless a shorter notice period is approved by the Director.

4. Within twenty-four (24) months of well completion, the permittee is required to submit to Ohio EPA an application for a Permit to Operate that, at a minimum, meets all requirements of OAC Rules 3745-34-12, 3745-34-13, and 3745-34-15 to be considered a complete application. If a complete application for a Permit to Operate is not submitted to Ohio EPA within this time frame, the permittee is required to begin implementation of its current and approved closure plan.

K. DUTY TO PROVIDE INFORMATION

The permittee shall furnish to the Director, within the time frame specified, any information which the Director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating the permit, or to determine compliance with the permit. The permittee shall also furnish to the Director, upon request, copies of records required to be kept by the permittee.

Part II
WELL SPECIFIC CONDITIONS

A. CONSTRUCTION REQUIREMENTS (OAC Rule 3745-34-54)

1. At a minimum, the permittee shall construct the well in accordance with the construction standards of OAC Rule 3745-34-54. All well materials shall be compatible with any fluids with which the materials may be expected to come into contact and designed for the life expectancy of the well.

2. The permittee shall follow drilling and construction procedures as set forth in the permittee's approved application, including all revisions submitted to and approved by Ohio EPA or as otherwise specified within this Permit to Drill. The proposed casing program and cementing procedures are included in Attachment B of this Permit to Drill. Appropriate mechanical and engineering practices shall be applied to ensure that the well pressure is controlled at all times.

   a. Only potable water shall be used for mixing while drilling conductor and surface casing or during completion of the conductor and surface casing installation.

   b. Conductor casing shall meet or exceed the standards as established in the Drilling Plan section of the permit application. The conductor shall be installed at a depth which adequately allows emplacement of the surface casing.

   c. Surface casing shall, at a minimum, extend at least 100 feet below the lowermost USDW and be cemented to surface using a minimum of 25% excess cement.

   d. Centralizers shall be placed to ensure adequate cementation of the casing and ensure protection of the USDW. At a minimum, surface casing shall be centralized at the shoe and on every second joint thereafter.

   e. Air drilling shall be utilized as much as possible below the surface casing interval, throughout the drilling process to an approximate depth of 5,695 feet, the top of the Rose Run formation (as determined from samples and drill rate). At approximately 5,695 feet, Buckeye Brine will switch to a water-based drilling media with plans to add potash and starch to provide appropriate weight and viscosity. Ohio EPA must be notified at least 24 hours in advance with the type of fluid and additives to be utilized.

   f. Before drilling below the surface casing, a blowout preventer, control head or other connections shall be installed to keep the well pressure under control at all times.

   g. Deviation checks shall be performed at no less frequently than: surface interval (17 ½" hole) +/- 500 feet from the base of the conductor to total depth; the protection interval (12 ¼" hole) deviation survey measurements should be obtained at sufficient frequency and spacing to ensure a complete and accurate calculation of the well path. The measured depth, inclination, and azimuth shall be recorded at each survey point. The data shall be used to monitor the well path, to determine the exact bottom hole location, and to assure that no vertical avenues are created which would allow fluid migration pursuant to OAC 3745-34-55(A)(1).

h. Long string casing with a sufficient number of centralizers shall extend to top of the the Rose Run Sandstone (~5,965 feet) and be cemented to surface. The cement volume shall be a minimum of 25% excess cement. This information is provided in Attachment B.

i. Long string casing centralizers shall, at a minimum, satisfy standards established in the permit applications. Centralizers shall be placed to ensure adequate cementation of the casing and to ensure that the lowermost USDW is protected. At a minimum, each joint of the bottom 500 feet of the long string casing shall be centralized, and subsequent centralizers shall be placed on every second joint to the surface thereafter.

j. Neither the cement nor associated cementing equipment shall be subject to the resumption of drilling until the cement has developed sufficient compressive strength to support the casing and restrict fluid movement between formations. The cement bond of each casing string shall be demonstrated by an approved bond log.

k. The permittee shall obtain representative samples of the cement mixture and additives for each cementing operation. At a minimum, samples shall be collected at intervals of approximately 25%, 50%, 75%, and 95% of the total volume used in each cementing operation. Laboratory analyses shall be performed for at least the following:

   i. Compressive strength;
   ii. Permeability; and
   iii. Fluid loss.

3. Under no circumstances shall drilling go beneath the Mount Simon formation and into the Precambrian, also known as the Middle Run.

B. REQUIREMENTS FOR DRILL CUTTINGS and CORES (OAC Rule 3745-34-55)

1. Drill cuttings shall, at a minimum, be sampled and collected at 10′ intervals beginning at 3,500 feet in the Dayton and Clinton formations. Samples will be collected from 3,500 feet to total depth (TD) at 10’ intervals, except in the Queenston Shale and Cincinnati Group (approximately 3,800 to 4,970 feet) due to increased drilling rates. Thirty-foot (30 ft) samples will be utilized in this interval. The cuttings shall be representative of the drilled intervals and be placed in appropriately labeled sample bags. The drill cuttings from the injection zone should be treated and disposed per solid waste requirements.

2. The permittee is responsible for the care and security of well cutting samples and any core that is obtained. If requested, drill cuttings and cores shall be delivered to the Ohio Department of Natural Resources’ Core Repository.

3. OAC 3745-34-55(B) requires that whole or sidewall cores of the confining and injection zones be taken. The locations of core samples will be determined based on open hole logs and in coordination with Ohio EPA. The permittee shall ensure that any extracted core is representative of the intended interval and that coring operations result in optimum core uniformity and recovery. Procedures for testing the core(s) shall be submitted to Ohio EPA for prior approval. OAC 3745-34-55(D)(2) and (3) requires that the permittee submit information detailing the physical and chemical characteristics of the confining and injection zones, including porosity, permeability, percent saturation, detailed descriptions, sieve analyses, and waste stream compatibility.

4. The Director may require additional coring if it is determined that cores extracted under Permit to Drill UIC 03-72-019-PTD-I are not adequate for satisfying the requirements of OAC Rule 3745-34-55.

C. GEOPHYSICAL WELL LOGGING REQUIREMENT (OAC Rule 3745-34-55)

At a minimum, the following electric and geophysical well logs (or equivalent logs) shall be performed unless otherwise approved by the Director: (All procedures must be pre-approved by Ohio EPA).

1. Prior to the installation of the surface casing:
   a. Gamma Ray;
   b. Spontaneous Potential;
   c. Lateral Induction Resistivity;
   d. Compensated Neutron Density;
   e. Compensated Formation Density; and,
   f. Caliper.

2. After surface casing has been set and cemented:
   a. Gamma Ray;
   b. Temperature;
   c. Cement Bond; and
   d. Variable Density.

3. Prior to installation of the long string casing:
   a. Gamma Ray;
   b. Spectral Gamma Ray;
   c. Photo electric;
   d. Spontaneous Potential;
   e. Lateral Induction Resistivity;
   f. Nuclear Magnetic Resonance (NRM);
   g. Compensated Neutron;
   h. Compensated Formation Density;
   i. Temperature;
   j. Fracture Identification;
   k. Long Spaced Sonic; and
   l. Caliper.

4. After long string casing has been set and cemented:
   a. Gamma Ray;
   b. Temperature;
   c. Cement Bond;
   d. Variable Density; and
   e. Casing Inspection.

5. After construction of the well and installation of the injection string and packer, the permittee shall provide a schedule and plan for Ohio EPA review and approval at least thirty (30) days prior to testing for the following:
   a. Baseline Differential Temperature Survey;
   b. Annulus Pressure Test;
   c. Radioactive Tracer Survey;
   d. Post-Injection Differential Temperature Survey; and,

e. Bottom Hole Pressure Falloff Test.

6. The above electric and geophysical well log requirements do not limit or relieve the permittee from other or additional logging or testing requirements which may be deemed necessary by the Director. The permittee shall notify Ohio EPA a minimum of twenty-four (24) hours prior to any well logging. This requirement does not apply to the mud log which will be performed continuously from the conductor casing shoe to total depth.

   Should cementing procedures or logging results indicate potential for an inadequate cement job, the permittee shall conduct all necessary operations to ensure a quality cement job.

D. FORMATION TESTING

1. In accordance with OAC 3745-34-37(E), 3745-34-38(A)(1), and 3745-34-55(D), the permittee shall provide an adequate demonstration of the fracture gradient. This demonstration including the fracture initiation, propagation, and closure pressures shall be submitted in the closure report or in the permit to operate application per Part I (H)(2). The permittee shall collect all data necessary to provide a conclusive demonstration. The permittee must obtain prior approval from Ohio EPA for all procedures to be performed to make this demonstration.

2. Should the permittee choose to perform a pump test or injectivity test, to fulfill the requirements of OAC Rule 3745-34-55(E), the test shall be conducted using an Ohio EPA approved fluid and method.

3. The above minimum testing requirements do not limit or relieve the applicant from additional testing if it is determined by Ohio EPA that additional testing is necessary. The permittee shall notify Ohio EPA at a minimum of twenty-four (24) hours prior to any formation testing.

E. FORMATION TESTING REQUIREMENTS

1. The permittee shall sample and analyze stabilized fluid samples in a manner that shall maximize accurate measurement of pH and chemical constituents. The permittee shall record the following minimum measurements after a representative wellbore volume has been purged, to ensure that formation parameters have stabilized:

   a. pH;
   b. Specific Gravity; and
   c. Specific Conductance.

2. Upon twenty-four (24) hour prior notice, a split sample of each recovered fluid sample shall be provided to Ohio EPA for analysis if requested. All sampling depths will be agreed upon by Ohio EPA prior to sampling.

3. All fluid samples sampled from the confining and injection zones shall be analyzed for a minimum of the following:

   a. pH;
   b. Conductivity;
   c. Total dissolved solids (TDS);
   d. Total suspended solids (TSS);

e. Alkalinity as $CaCO_3$ (M);
f. Specific Conductance;
g. pH;
h. Resistivity
i. Sodium;
j. Boron;
k. Calcuim;
l. Iron;
m. Potassium;
n. Manganese;
o. Sulphate;
p. Ammonia;
q. Chloride;
r. Fluoride;

4. In accordance with Ohio Revised Code Section 6111.043(D), the permittee shall submit to the Director any information or test results that the Director determines is necessary to more adequately define hydrogeologic conditions at the site of the well and to protect the lowermost USDW.

F. INJECTION PRESSURE LIMITATION (OAC Rule 3745-34-56)

1. Except during stimulation or testing approved in advance by Ohio EPA, injection pressure at the wellhead shall not initiate new fractures or propagate existing fractures in the injection zone. In no case shall injection pressure initiate fractures or propagate existing fractures in the confining zone or cause the movement of injection or formation fluids into a USDW. Maximum bottom hole pressure and maximum surface injection pressure shall be calculated using the equations in Attachment A.

2. Injection between the outermost casing protecting USDWs and the wellbore is strictly prohibited. At no time shall injection occur into any formation without prior approval from Ohio EPA.

3. Unless otherwise approved in advance by Ohio EPA for construction, stimulation or testing of the well, no fluids shall be injected into this well prior to receipt of a final Permit to Operate issued by the Director of Ohio EPA and any conditions set forth therein.

4. Injection necessary to conduct well testing or stimulation shall be conducted in accordance with limitations established in Part I(F)(4) of this permit.

G. INJECTION FORMATION STIMULATION PREREQUISITE

1. Hydraulic fracture stimulation of the injection formation is prohibited unless the permittee has secured written approval from Ohio EPA. To receive authorization from Ohio EPA to fracture stimulate the injection formation, the permittee must demonstrate that such stimulation shall not initiate fractures in the confining zone or cause movement of injection or formation fluids into a USDW.

2. If the permittee chooses to perform an acid stimulation of the injection formation the permittee must submit a plan to Ohio EPA for approval. The permittee must demonstrate that the injection pressure does not exceed the formation fracture pressure.

H. RECORD REQUIREMENTS

1. Records of all sampling, testing, and analysis shall include:
   a. The date, exact place, and time of sampling, testing, or measurements;
   b. The individual(s) who performed the sampling, testing, or measurements;
   c. A precise description of sampling and testing methodology and the handling of samples thereof;

d. The date(s) analyses were performed;
e. The name(s) of individual(s) who performed the analysis;
f. The analytical techniques or methods used; and
g. The results of the analyses.

2. At all times throughout the drilling and construction of the well, the permittee shall maintain a drilling record at the well site. At a minimum, the drilling record shall note and record the following:
   a. Current depth;
   b. Drilling rate of penetration (drilling time log);
   c. Lithology;
   d. Size of drill bit;
   e. Water/fluid bearing zone(s);
   f. Oil and gas shows;
   g. Lost circulation zone(s);
   h. Deviation survey results, including bottom hole location;
   i. Drilling fluid information, at a minimum shall include:
      i. Depth;
      ii. Weight;
      iii. Viscosity;
      iv. Fluid loss test;
      v. Specific conductance; and
      vi. pH.

3. Ohio EPA shall be granted access to view, examine, take notes from and/or copy the drilling record at all times. Within thirty (30) days of completion of drilling and construction operations, a copy of the drilling record shall be delivered to Ohio EPA.

4. The permittee shall inform Ohio EPA of the progression and scheduling of drilling and testing daily. A written daily driller's report shall be submitted electronically. At a minimum, the daily drilling report shall contain the following information:
   a. General information:
      i. Date and time of report;
      ii. Well depth;
      iii. Formation;
      iv. Lithology;
      v. Comments; and
      vi. Name/title of person preparing the report.

   b. Daily drilling and completion report:
      i. Report date;
      ii. Spud date;
      iii. Current drilling depth;
      iv. Present operation (e.g. drilling, waiting on cement, etc.);
      v. Casing/Cementing data – at a minimum date set, depth, casing size diameter, centralizer locations, sacks of cement;
      vi. Bit data – bit number, size, type, hours in use, footage drilled, weight on bit, revolutions per minute;
      vii. Mud data – at a minimum, items in Part II (H)(3)(i) of the permit to drill; and,
      viii. Summary of activities since the previous report.

c. Activities, including those outlined in the drilling plan, projected to occur during the next twenty-four (24) hours.

I. WELL CLOSURE PLAN

1. At a minimum, the permittee shall plug and abandon the well in accordance with the standards set forth in OAC Rules 3745-34-36, 3745-34-39, and 3745-34-60. Closure and Post-Closure plans are provided in Attachment D.

2. The permittee shall inform Ohio EPA of their intentions to plug and abandon the well at least sixty (60) days prior to the scheduled plugging date. The permittee shall obtain Ohio EPA approval of the closure plan prior to initiating plugging and abandonment operations.

3. The permittee shall provide a report of the plugging and abandonment to Ohio EPA within sixty (60) days after completion of the plugging and abandonment activities.

Attachment A

Maximum Allowable Bottom Hole Pressure and Maximum Allowable Surface Injection Pressure.

The maximum allowable bottom hole pressure (BHP_{max}) shall be calculated using the following formula:

BHP_{max} = (Formation Fracture Gradient) (Long String Casing Depth)

BHP_{max} = .75 psi/ft X 5,965′ (Long String Casing Depth)

BHP_{max} = 4473 psi

The maximum allowable surface injection pressure (MASIP) shall be calculated using the following formula:

MASIP = Buckeye Brine requested that the MASIP be set at 1362 psi, per their calculations.

III.B.2. Maximum Surface Injection Pressure

The maximum proposed surface injection pressures for Adams #3 was calculated relative to the density of the fluid being injected.

Buckeye Brine is requesting that the Maximum Allowable Surface Injection Pressure (MASIP) be set for the Adams # 4 well as shown in Table III.C below.

Table III.C. MASIP Calculation for Adams #4 Well

	SPG	Frac Gradient		PSI/Ft By SPG	Hydrostatic Difference		Adams #1 MASIP	Based on SPG	Adams #3 MASIP
						Frac Gradient x 0.75 Depth	5898		5912
						BHP Maximum	4424		4434
	1.01	0.75	Minus	0.4373	0.3127	Times depth	1844	1.01	1849
	1.02	0.75	Minus	0.4417	0.3083	Times depth	1819	1.02	1823
	1.03	0.75	Minus	0.4460	0.3040	Times depth	1793	1.03	1797
	1.04	0.75	Minus	0.4503	0.2997	Times depth	1768	1.04	1772
	1.05	0.75	Minus	0.4547	0.2954	Times depth	1742	1.05	1746
	1.06	0.75	Minus	0.4590	0.2910	Times depth	1716	1.06	1721
	1.07	0.75	Minus	0.4633	0.2867	Times depth	1691	1.07	1695
	1.08	0.75	Minus	0.4676	0.2824	Times depth	1665	1.08	1669
	1.09	0.75	Minus	0.4720	0.2780	Times depth	1640	1.09	1644
	1.1	0.75	Minus	0.4763	0.2737	Times depth	1614	1.1	1618
	1.11	0.75	Minus	0.4806	0.2694	Times depth	1589	1.11	1593
	1.12	0.75	Minus	0.4850	0.2650	Times depth	1563	1.12	1567
	1.13	0.75	Minus	0.4893	0.2607	Times depth	1538	1.13	1541
	1.14	0.75	Minus	0.4936	0.2564	Times depth	1512	1.14	1516
	1.15	0.75	Minus	0.4980	0.2521	Times depth	1487	1.15	1490
	1.16	0.75	Minus	0.5023	0.2477	Times depth	1461	1.16	1465
	1.17	0.75	Minus	0.5066	0.2434	Times depth	1436	1.17	1439
	1.18	0.75	Minus	0.5109	0.2391	Times depth	1410	1.18	1413
	1.19	0.75	Minus	0.5153	0.2347	Times depth	1384	1.19	1388
Current DNR MASIP	**1.2**	**0.75**	**Minus**	**0.5196**	**0.2304**	**Times depth**	**1359**	**1.2**	**1362**

Per Ohio EPA's MASIP Calculations:

Long String Casing Depth X [Formation Fracture Gradient – (Pressure Gradient of One Foot of Water at 62 Degrees Fahrenheit (.433) X Maximum Specific Gravity (1.00*))]

.75 - .433 = .317

5,965' X .317 = 1890.90

MASIP = 1,890 psi**

*** If specific gravity over 1.0, MASIP must be adjusted downward accordingly.**

**** Per Ohio EPA's calculations, the MASIP shall not exceed 1890 psi. Buckeye Brine must obtain written permission from Ohio EPA if 1362 psi may be exceeded.**

Attachment B

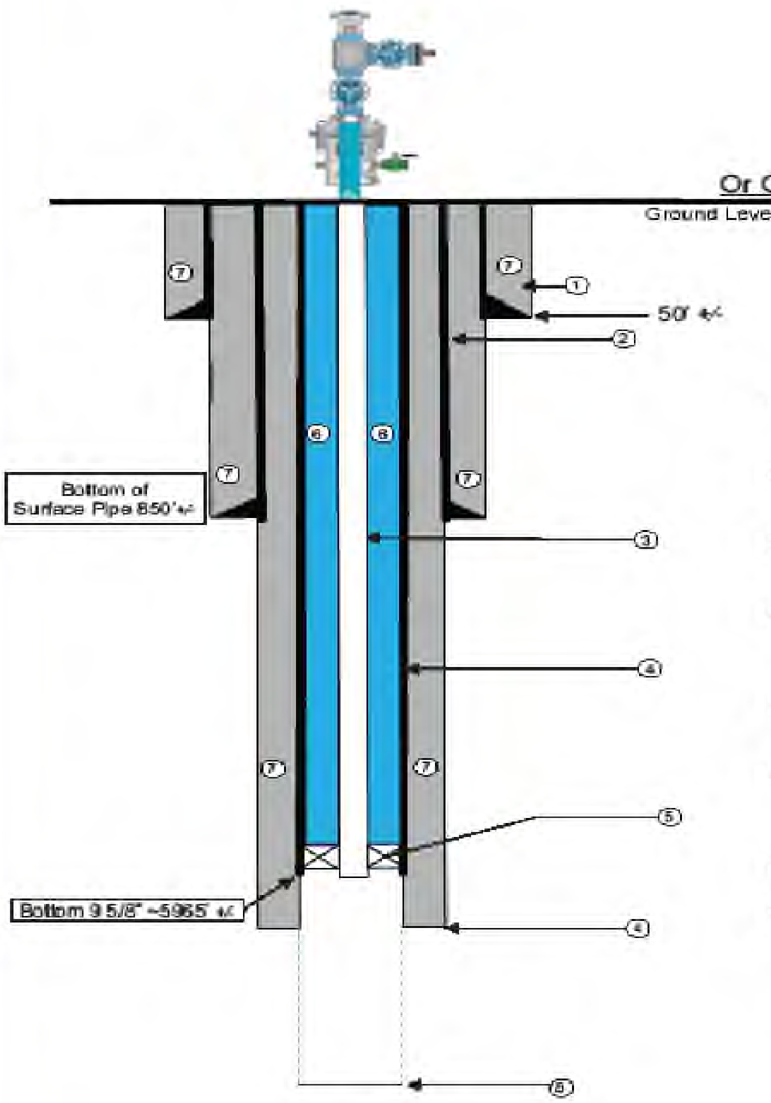
I. Proposed Well Diagram
II. Proposed Casing and Cementing Programs
III. Proposed Well Completion

Attachment B

I. Proposed Well Diagram

Figure is Not to Scale

Or Other Based on Availability (OOBOA)



BELOW GROUND DETAIL

1. Conductor Casing: 50' of 20" ST&C. Cemented to surface.
2. Surface Casing: 850' +/- of 13 3/8", ST&C. Cemented to surface.
3. Injection Tubing: 5950' +/- of 4 1/2" 10.5 #/ft J-55, OOBOA
4. Protection/Longstring Casing (bottom to top): 5965' +/- , 9 5/8" LT&C 36#. Cemented to surface OOBOA
5. Packer: ASI-X Nickel internal Coated mandrel from 5950' +/- to 5962' +/-.
6. 10# Brine Water Pkr Fluid: Annulus fluid with oxygen scavenger & corrosion inhibitor.
7. Cement:
8. TD 7000' +/-

	CLIENT	PROJECT DESCRIPTION	FIGURE
	Buckeye Brine, LLC	Proposed Adams # 4	DATE: 11/19/21 Wellbore Schematic of Adams #4

Attachment B

II. Proposed Casing and Cementing Programs

III.A.2. Adams # 4 Total Depth

The Adams # 4 well will be drilled to a total depth of about 7,000 feet below ground level. The final choice of the total depth will ultimately be based on the type of cuttings and bit resistance that is observed by the geologist on-site during the last phase of drilling. Buckeye will engage local drilling supervisors that are familiar with the indications that the bit is turning in the lower confining zone. It is probable that OEPA personnel will be onsite to witness the final stages of the borehole drilling and to opine about the TD if they feel it would be useful.

III.A.3. Well Casing and Tubing Strings

The Adams #4 well is designed to exceed the requirements for Class I injection wells and is constructed with steel conductor casing, surface casing, longstring casing, and injection tubing. steel casing and tubing. Factors calculated and reviewed to guide the selection of the proposed casing and tubing program including:

- Hole sizes;
- Injection zone and injection interval depths;
- Depth of lowermost underground source of drinking water (USDW);
- Injected waste and formation fluid composition, corrosiveness and compatibilities;
- Injection rates and operating pressures (annular and wellhead);
- Casing and tubing sizes, weights, grades, and mechanical strength properties; and
- Types and grades of cement.

III.A.3.a. Casing and Injection Tubing- Type, Weight, Grade, Wall Thickness, End Finish, Set Depth, and Life Expectancy

The casing and tubing strings will be made up of conductor pipe, surface casing, longstring casing, and injection tubing.

Conductor Pipe

Size (OD)	20 inches
Internal Diameter	19.124 inches (18.936” drift ID)
Weight	94 lb./ft.
Grade	K-55
End Finish	Welded (ST & C)
Setting Depth	50 feet – Cemented to Surface
Life Expectancy	>30 years (life of well)

Surface Casing

Size (OD)	13.375 inch OD
Internal Diameter	12.515 (12.359" drift ID)
Weight	61 lb./ft.
Grade	J-55
Coupling Size	14.375 inches
Thread	ST & C
Setting Depth	850 feet (approx. 500 ft. below lowermost USDW) Cement to surface
Life Expectancy	>30 years (life of the well)

Longstring Casing

Size (OD)	9.625" inch OD
Internal Diameter	8.921 (8,765 drift ID
Weight	36 lb./ft.
Grade	J-55
Thread	LT & C
Setting Depth	5,965 feet – Cemented to surface
Life Expectancy	>30 years (life of the well)

Injection Tubing

Size (OD)	4.5
Internal Diameter	4.052 inches (3.927" drift ID)
Weight	10.5 lbs./ft.
Grade	J-55
Setting Depth	5,950

Note: The top of the packer will be set between 5950 and 5962' BGL. The external and internal forces on the injection tubing and longstring casing are not active below this depth. For tensile strength comparisons on the injection tubing and longstring casing, the full installed length is used

III.A.3.b. Tubulars- Collapse Resistance, Internal Yield Pressure, Joint Strength, Yield Strength

The casing and tubing strings will be made up of conductor pipe, surface casing, longstring casing and injection tubing.

Conductor Pipe (20", 94 lb./ft., K-55)

Collapse	520 psi
Burst (internal yield)	2,110,psi
Joint Strength	824,000 lbs.
Yield Strength	1,480,000 lbs.

***(Source: IPSCO On-Line Handbook: Dimensions and Performance Properties for Tubing and Casing)**

Surface Casing (13.375", 61 lb./ft. J-[55, ST&C)

Collapse	1,540 psi
Burst (internal yield)	3,090 psi
Joint Strength	595,000 lbs.
Yield Strength	962,000 lbs.

*(Source: IPSCO On-Line Handbook: Dimensions and Performance Properties for Tubing and Casing)

Longstring Casing (9.625", 36 lb./ft, J-55, LT&C)

Collapse	2,020 psi
Burst (internal yield)	3,520 psi
Joint Strength	453,000 lbs.
Yield Strength	564,000 lbs.

*(Source: IPSCO On-Line Handbook: Dimensions and Performance Properties for Tubing and Casing)

Injection Tubing 4.5", 10.5 lb./ft., J-55

Collapse	4,010 psi
Burst (internal yield)	4,790 psi
Joint Strength	132,000 lbs.
Yield Strength	165,000 lbs.

*(Source: IPSCO On-Line Handbook: Dimensions and Performance Properties for Tubing and Casing)

III.A.3.c. Casings and Injection Tubing- Maximum External and Internal Pressures and Axial Loading Conditions during Construction, Operation, and Closure

The casing and tubing strings will be subject to different stresses during the different phases of construction, operation, and closure. An analysis is presented below to determine the maximum stresses during any of these phases. For any other condition, the stresses on the component will be less. The assumptions made here maximize the calculated stress on the component and will represent the maximum during construction, operation, and closure procedures.

External Pressures - Casings

For the maximum external pressure, it is conservatively assumed that somehow the inside of the casing in question has become entirely evacuated from surface to its total depth with only atmospheric pressure on the inside and that a maximum formation hydrostatic pressure (assuming a 10 lb./gal equivalent mud weight) is exerted against the external surface of the casing. This condition is assumed to occur during the casing installation phase but could also occur during jet-back cleanout operations and closure. In any event, these conditions are very unlikely to occur but are nonetheless presented here to provide a conservative outcome.

Design Formation Pressure

For the casing and tubing design, the formation pressure gradient is assumed to be 0.52 psi/ft. or a 10 lb./gal equivalent fluid density. See a justification for this pressure immediately below.

Measured Ambient Formation Pressure from Existing Wells

Ambient pressure measurements have been obtained from all three existing wells on the Buckeye site during scheduled MIT testing. On October 19, 2016, the static BHP in the Adams #3 was measured to 3,331 psig at a depth of 7,000 ft. BGL. The measured BHP divided by the depth indicates that the formation pressure gradient was 0.476 psi/ft. (3,331/7,000). For comparison, the gradient in the Adams #1 well was calculated to be 0.474 psi/ft. based on a static BHP measured in that well on October 18, 2016. For a conservative evaluation, we assumed that the ambient formation pressure gradient of 0.52 psi/ft. (10 lb./gal equivalent density). The resulting equation is:

T_{ext} = 10 lb./gal*0.052 psi/ft. / lb./gal* Casing Depth

= 0.52 psi/ft. * Casing Depth (ft.) **... (i)**

External Max $Press_{conductor}$ = 0.52 psi/ft. * 50 ft. **= 26.0 psig**

External Max $Press_{surface}$ = 0.52 psi/ft. * 850 ft. **= 442 psig**

External Max $Press_{longstring}$ = 0.52 psi/ft. *5,965 ft. **= 3,101.8 psig**

Internal Pressures - Casings

For the maximum internal pressure, it is conservatively assumed that somehow the outside of the casing has become entirely evacuated from surface to its total depth with only atmospheric pressure on the outside and that a 10 lb./gal equivalent mud weight is exerted against the internal surface of the casing. The resulting equation is given by (same as previous):

P_{int} = 10 lb./gal*0.052 psi/ft. / lb./gal* Depth of Casing

= 0.52 psi/ft. * Depth of casing (ft.) **... (ii)**

Internal Max Press$_{conductor}$ = 0.52 psi/ft. * 50 ft.
=26.0 psig

Internal Max Press$_{surface}$ = 0.52 psi/ft. * 850 ft.
= 442 psig

Internal Max Press$_{longstring}$ = 0.52 psi/ft. *5965 ft.
= 3,101.8 psig

Axial Loading - Casings

For the maximum load, it is conservatively assumed that the casing is "hanging in air" with no buoyant force exerted by the circulating fluid or surrounding formation in the borehole. This unrealistic condition could only be realized if the borehole somehow became fully evacuated of fluids and had no circumferential contact with the walls of the borehole. Nevertheless, it is used here for a worst possible case condition. The resulting equation is given by:

Max Tension Load = Weight of Casing (lb./ft.) * Depth of Casing (ft.) … (iii)

MaxTensionLoad$_{conductor}$ = 94lb./ft. *50 ft. = 4,700 lbs.

MaxTensionLoad$_{surface}$ = 61 lb./ft. * 850 ft.
= 51,850 lbs.

MaxTensionLoad$_{longstring}$ = 36 lb./ft. *5,950 ft.
= 214,200 lbs.

External Pressures - Injection Tubing

For the maximum external pressure, it is conservatively assumed that maximum external pressure is equal to the maximum allowable surface injection pressure plus an additional 100 psi. For the existing Adams #3 this pressure is 1,462 psig (MASIP = 1,362 psig) + 100 psig additional differential pressure). It is probable that the MASIP calculated for Adams # 4 will be very close (within 20 psig +/- of 1462). This represents the maximum possible condition during annulus pressure testing at Buckeye Brine.

During injection operations, the well is operated with much less differential pressure. Additionally, it is assumed that the annulus fluid is a base solution in 10 lb./gal the maximum annulus fluid density, although it may be something less. Finally, it is assumed that there is no injection pressure (no injection) and that the tubing fluids are in equilibrium with the injection interval. At Buckeye Brine, the minimum static injection interval pressure in the Adams #3 is 3,331 psig at 7,000 feet, corresponding to a hydrostatic gradient of 0.476 psi/ft. Therefore, to calculate the maximum external (differential pressure at the bottom joint of injection tubing):

External MaxPress$_{inj.tubing}$ = 10 lb./gal*0.52 psi/ft. / lb./gal* Depth of injection tubing (ft.) + 1,462 psig – 0.476 psi/ft.* injection tubing depth ...(iv)

With the known proposed values:

External MaxPress$_{inj.tubing}$ =0.52 psi/ft.*5,950- feet +1,462 psig – 0.476 *5,912 feet

Max External Press$_{inj.tubing}$ = 1,742 psig

Internal Pressures - Injection Tubing

For the maximum internal pressure exerted on the injection tubing, it is assumed that 10 lb./gal fluid is being injected into the well at the maximum allowable injection pressure (1,362 psig) and that the annulus is filled with fresh water. A column of water, in this case, the annulus, exerts a downward and outward force of 0.433 psig/ft. With a column of freshwater inside the annulus and with no external pressure added at the surface, the pressure at the lowest point in the tubing above the packer would be 5,902 ft. X 0.433 psig/ft. or 2,556 psig at 5902 ft. The resulting equation which incorporates the weight of water in the annulus is given by:

InternalMaxPress$_{inj.tubing}$= 0.52 psi/ft. * tubing depth (ft.) +1,362 psig - 0.433 psi/ft.* depth of injection tubing ...(v)

Internal MaxPress$_{inj.tubing}$ = [(0.52 psi/ft.*5,950 ft.) +1,362 psig]- [0.433 psi x 5,950 ft.]

Max Internal Press$_{inj. tubing}$ = 1,880 psig

Axial Loading - Injection Tubing

For the maximum tensile load, it is conservatively assumed that the injection tubing is latched into the packer with no buoyant force exerted by the annular fluid or fluid inside the injection tubing, and that there is no additional tensional loading pulled on the injection tubing (normally 10,000 – 15,000 lbs. of slackoff weight is stacked onto the packer). Finally, it is assumed that the injection string is cooled by 50° F, relative to the ambient temperature at which it was landed. The resulting equation is given by:

Max Load = Tubing Wt (lb./ft.) *Tubing Depth (ft.) + thermal contraction (lbs.)

...(vi)

Calculate thermal contraction load from temperature change for 50° F cooling:

Thermal Tension (lbs.) = 207* As * ΔT **...(vii)**

(source: Baker Oil Tools Technical Handbook, 1995)

Where;

As = cross-sectional area of tubing = $(4.50^2 - 4.05^{2)} * \pi/4 = 3.022 \text{ in}^2)$

ΔT = temperature change (cooling in this case) = 50° F

207 = units conversion factor

= 207 * 3.022 in^2 * 50° F

= 31,278 lbs.

Finally, from equation (vii) above:

Max Tensile Load$_{\text{injection tubing}}$ = 10.5 lbs./ft. * 5,950 ft. + 31,278 lbs.

= 93,753 lbs.

III.A.3.d. Detailed Factor of Safety Calculations for Each Tubular String

Given the strength of the materials that comprise the proposed well casings and injection tubing, along with the calculated maximum conceivable stress on well components. The conditions described in the calculations are, in most cases, impossible to achieve during the operation and maintenance of the well. Safety factors can be determined for each component through the equation:

SF = 1 + {(Material Strength – Max. Calculated Stress) / Max calculated Stress (viii)

The casing strings (conductor, surface, and longstring) will be considered in I) through III) below and then the injection tubing will be considered.

I) Safety Factor for External Collapse Strength for Casings

Conductor Pipe (20", 91 lb./ft., K-55, ST & C)

$SF_{conductor}$ = 1 + (520 psi – 26 psi) /26 psi

$SF_{conductor}$ = 20.0

Surface Casing (13.375", 61 lb./ft.,J-[55, ST&C)

$SF_{surf\ casing}$ = 1 + (1,560 psi – 442 psi) /442 psi

$SF_{surf\ casing}$ = 3.53

Longstring Casing (9.625", 36 lb./ft,, J-55, LT&C

$SF_{longstring\ csaing}$ = 1 + (2020 psi – 3,101 psi) / 3,101 psi

$SF_{longstring\ casing}$ = 0.65

II) Safety Factor for Internal Yield Strength for Casings

Conductor Pipe (20", 94 lb./ft., K-55, ST & C)

$SF_{conductor}$ = 1 + (2,110 psi – 26.0 psi) / 26.0 psi

$SF_{conductor}$ = 81.2

Surface Casing (13.375", 61.0 lb./ft., J-55, ST&C)

$SF_{surf\ casing}$ = 1 + (3090 psi – 442 psi) / 442 psi

$SF_{surf\ casing}$ = 6.99

Longstring Casing (9.625", 36 lb./ft,, J-55, LT&C

$SF_{longstring\ csaing}$ = 1 + (3,520 psi – 3,102 psi) / 3,102 psi

$SF_{longstring\ casing}$ **= 1.13**

III) Safety Factor for Tensile Strength for Casings (use lessor of joint strength or yield strength, as appropriate)

Conductor Pipe (20", 94 lb./ft., K-55, ST & C)

$SF_{conductor}$ = 1 + (824,000 lbs. – 4,700 lbs.) /4,700 lbs.

$SF_{conductor}$ = 175.3

Surface Casing (13.375", 61.0 lb./ft., J-55, ST&C)

$SF_{surf\ casing}$ = 1 + (962,000 lbs. – 51,850 lbs.) /51,850 lbs.

$SF_{surf\ casing}$ = 18.6

Longstring Casing (9.625", 36 lb./ft,, J-55, LT&C

$SF_{longstring\ csaing}$ = 1 + (453,000 lbs – 214,200 lbs) /214,200 lbs.

$SF_{longstring\ casing}$ **= 2.11**

IV) Safety Factor for External Collapse Strength for Injection Tubing

SF = 1 + (4,010 psi – 1,728 psi) /1,728 psi

$SF_{inj\ tubing}$ = 2.32

V) Safety Factor for Internal Yield Strength for Injection Tubing

$SF_{inj.tubing}$ = 1 + (4,790 psi – 1,875 psi) / 1,875 psi

$SF_{inj.tubing}$ = 2.56

III) Safety Factor for Tensile Strength for Injection Tubing

Includes load for weight and thermal contraction, as discussed in Section III.A.3.c above, for Maximum Injection Tubing Stress:

$SF_{inj.tubing}$ = 1 + (132,000 lbs. – 93,333 lbs.) / 93,333 lbs.

$SF_{inj.tubing}$ = 1.41

In summary, the sizes, weights, grades, coupling systems, and materials of construction for the proposed new well casings and injection tubing are more than adequate for use in the proposed new well at the Buckeye Brine facility, even when considering maximum calculated conditions that greatly exceed what is expected, or that is even possible in most cases.

III.A.3.e. Injection Packer Specifications- Size, Type, Life Expectancy, and Setting Depth

The packer proposed for use is a 4.5-inch x 9 5/8-inch ASI-X set, with the top of the unit set near 5,950 feet BGL. The exact depth of placement will be determined based on field conditions and consultation with OEPA. The specification sheet for the packer is attached as Figure III.B at the end of this section.

III.A.3.f. Selection of Tubulars

The well design includes tubular selected based on strengths, grade, and depths related to:

- Depths of lowermost USDW, injection interval, and zone;
- Volumes of wastes to be injected;
- Pressures under static and injection conditions;
- Fluid properties (density, composition, corrosive properties, temperature) of injection and formation fluids; and
- Subsurface conditions (pressures, temperatures).

As discussed above in the detailed calculations regarding the strengths of the various casings and tubular components (Section III.A.3.d), the well components are of sufficient strength to withstand a reasonable potential stress projection with substantial multiples of design capability.

Lowermost USDW Protection

The lowermost USDW is predicted to extend to approximately 330 feet below ground surface at the Adams # 4 proposed location (see Section II). The potential depths at which the lowermost USDW could be present at the borehole location will be covered by two separate casing strings (surface casing and longstring casing). The surface casing, which is proposed to extend to a depth of 850 ft BGL, and the longstring casing, proposed to extend to a depth of approximately 5965 ft. BGL, will be cemented to the surface. An OEPA staff member is expected to be onsite during the cementing of the casings. Copies of the "Cement Tickets" provided by the cementing company will be reviewed to assure that returns to surface are observed during cementing of the conductor, surface, and longstring casings.

Cement bond logs will be run after adequate curing time has been allowed following cementing of each casing.

Reservoir and Injected Fluid Temperature and Pressure Considerations

The static bottom-hole temperature at TD was measured at 145° F before injection began in the Adams # 3. well Logs run during subsequent annual mechanical integrity tests indicate that the maximum temperature observed at 7,000 ft. BGL is approximately 133° F. During mechanical integrity testing performed on October 19, 2016, the static reservoir pressure at 7,000 ft. BGL was measured to be 3,331 psig. Coupling the pressure increase at the maximum allowable permitted injection pressure (1,362 psig) with a maximum permitted injection fluid specific gravity of 1.2 would result in a maximum bottom-hole reservoir pressure of 4,693 psig:

Measured BHP at depth 7,000 ft. + surface pressure at MASIP =max bottom hole pressure

3,331 + 1,362 = 4,693 psig.

While there are no industry standards that define High-Pressure High Temperature (HPHT) reservoir conditions, Schlumberger suggests that HPHT conditions begin above 300° F and 10,000 psig. These conditions are not present at Buckeye Brine. Furthermore, the design calculations and factor of safety calculations presented in Section III. A3.c-d demonstrate that the selected tubular is more than sufficient to meet the expected maximum possible adverse conditions at Buckeye Brine.

III.A.4. Type of Completion and Completion Interval

The type of completion proposed for the Adams # 4 is an open borehole that begins at the bottom of the longstring casing (approx. 5,965 ft. BGL) and extends to approximately 7,000 ft. BGL. A schematic of the proposed well construction design is provided as Figure III.A.

III.A.5. Centralization Program

A float shoe and float collar will be run on the longstring casing to facilitate adequate cementing and cement bonding. A bottom joint float collar will be installed 10 ft. from the bottom of the casing and centralizers installed on the first 10 joints run into the well.

III.A.6. Proposed Annulus (Packer) Fluid

The proposed packer fluid will consist of freshwater with a commercial corrosion inhibitor and oxygen scavenger added at concentrations recommended by the supplier of the additives. The annulus fluid management system includes a 300-gallon poly tank for storage of the treated freshwater.

III.A.7. Injection Well Construction & Completion

See Attachment III.A.7.

III.A.8. Cementing Program

OEPA regulations require that Class 1 injection wells be constructed such that cement is emplaced between the exterior wall of the surface casing and the borehole along its full length. The requirement for emplacing cement between the entire length of the casing and the borehole is the same when cementing the longstring casing.

To achieve a complete filing of the casing to borehole space, the volume of the borehole minus the volume displaced by the casing itself must be calculated for the conductor, surface, and longstring casings. Irregularities in the borehole diameter make it impossible to calculate the exact volume of cement required to create a visual confirmation of cement displaced to the surface. The percentage of excess cement to prepare for each casing should be based on drilling fluid losses at the depths that cement will pass through when circulated. Caliper logs should be reviewed to confirm borehole dimensions Table III.A.8. summarizes the cement volume calculations for the proposed Adam #4 well.

Table III.A.8

Conductor Cementing -20 inch K-55

Type	Composition	Density	Slurry Volume Estimate*		
			Nominal displacement per 100 feet (bbls)	Borehole Volume assume no washouts per 100 feet	Total cement needed by calc plus 100% excess
Conductor Cement (50 ft to Surface)	Class A cement + Additives	16.6 ppg	3.329	55.95 bbls	52.62 bbls

Surface Cementing—(13.375 in nominal, J55) 0 ft.BGL to 850 ft.BGL

Type	Composition	Density	Slurry Volume Estimate*		
			Nominal displacement per 100 feet	Borehole Volume assume no washouts per 100 feet	Total cement needed by calc plus 100% excess
Cement (850 ft BGL to Surface)	SurfaceSET cement blend + Additives	15.56 lb/gal	2.165 bbls	29.73 bbls	351.49468.65 bbls

Long String Cementing (9.625 in nominal LT & C) 0 ft.BGL to 5965 ft BGL

Type	Composition	Density	Slurry Volume Estimate*		
			Nominal displacement per 100 feet (bbls)	Borehole Volume assume no washouts per 100 feet	Total cement needed by calc plus 50% excess
Preflush	Chem Wash	8.3 lb/gal			10 bbls
Spacer	Mud Push Express	13.0 lb/gal			60 bbls
Cement (Casing Point to Surface	FlexSeal H cement blend + additives	16.0 lb/gal	1.268 bls	14.56	• 1,190 bbls • 50% excess over calculated. • Cement returns to surface

- All volumes predicted may change based on conditions encountered in the field. Where brand name products are listed, Buckeye reserves the right to substitute products supplied by other vendors if the product is deemed to be equivalent or superior to the product it is replacing

Attachment B

III. Proposed Well Completion

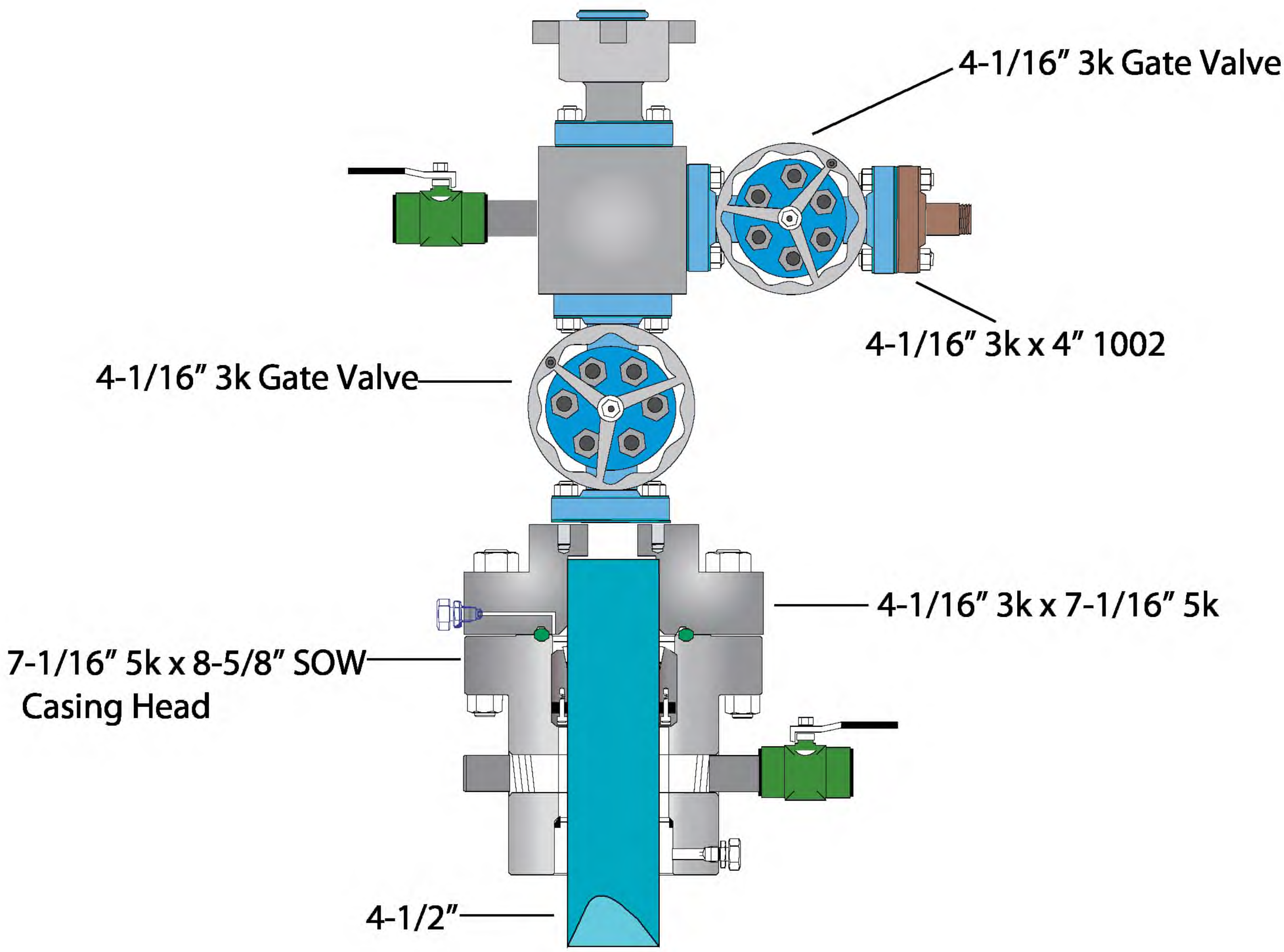
Figure III.C Wellhead Assembly
Adams #4

UNIVERSAL WELLHEAD SERVICES, LLC.

Schematic

Buckeye Brine

Adams #4



Weatherford

Arrowset I-XS Mechanical Packer

Weatherford's Arrowset I-XS mechanical packer is a versatile, field-proven retrievable double-grip packer for isolating the annulus from the production conduit. The packer can be set with tension or compression.

A patented upper-slip releasing system reduces the force required to release the packer. A nondirectional slip is released first, making it easier to release the other slips. The packer also has a straight-pull safety release.

Applications

- Production
- Pumping
- Injection
- Fiberglass tubing
- Completions requiring periodic casing-integrity tests
- Zonal isolation

Features, Advantages and Benefits

- The design holds differential pressure from above or below, enabling the packer to meet most production, stimulation, and injection needs.
- The packer can be set with compression or tension, enabling deployment in shallow and deep applications.
- The packer can be set and released with only a one-quarter turn of the tubing.
- The bypass valve is below the upper slips so that debris is washed from the slips when the valve is opened, reducing the times for circulation and total retrieval.
- The packer can be run with Weatherford's T-2 on-off tool, which enables the tubing to be disconnected and retrieved without retrieving the packer.

Figure III.B Packer Schematic

Attachment C

I. Geology Description
II. Seismic Discussion

Attachment C

I. Geology Description

II.A REGIONAL GEOLOGY

II.A.1 REGIONAL STRATIGRAPHY

PRECAMBRIAN

Based on drill cuttings in the Area of Review (AOR), as well as other basement tests within a 25-mile radius of the AOR, the Precambrian in the vicinity of the area of review (AOR) has been determined to be granitic in composition. Drilling experiences and wireline logs suggest that the upper portion of the Precambrian may be present as a so-called "granite wash," either a highly weathered and/or detrital form of the native rock that is relatively easy to drill. The paleotopography of the Precambrian surface is typically irregular due to a combination of differential erosion and mild tectonics. Although relief of up to 300 ft. is possible, it is more typically of a very low scale. Wireline log control is too thin to put much detail to the surface form of the Precambrian in the AOR, but seismic data in eastern Ohio routinely shows such a surface.

II.A.1.a CAMBRIAN PERIOD

Mt. Simon/Basal Sand

The Mt. Simon Sandstone is the lowermost of the Cambrian units. It ranges in thickness from about 350 ft. in western Ohio and thins to about 100 ft. in eastern Ohio. In western Ohio it is a fine to coarse-grained quartz sand with a moderate to light carbonate cement, and commonly possesses moderate to excellent porosity (to 15%) and low to high permeability (0.1-10,000 mD). On the eastern edge of Ohio the Mt. Simon sandstone is a very fine-grained quartz sand with a robust carbonate cement. The net sand thickness in an approximately 100 ft. interval in the vicinity of Coshocton is commonly less than 40 ft. Porosity as determined from wireline logs is typically less than 10%. Permeability is low, as determined from tests and observations while drilling in Coshocton and adjacent Counties. It has been offered by some that the sand as it exists on either side of the State is not the same formation. Accordingly, the lesser sand in the eastern part of the State is sometimes informally referred to simply as the "basal sand."

Rome Formation

What is called the Rome Formation (Janssens, 1972) in eastern Ohio is a thick, white to light gray, micro- to finely crystalline section of 350-750 ft. thick dolomite. It is considered as having two identifiable parts, a lower arenaceous dolomite section and an upper pure dolomite section. The basal portion of the unit is upwardly transitional from the underlying Mt. Simon Sandstone. The upper portion of the Rome Formation may be sucrosic in parts of the section, but is generally considered to be non-porous. The upper boundary of the Rome Formation is considered an unconformity surface.

Conasauga Formation

Throughout much of the literature the Conasauga Formation has been identified as a shale, though it is in fact a sequence of interbedded dolomite, argillaceous dolomite, and shale across most of eastern Ohio. Thin, erratically developed sandstones may be present in the lower part of the unit. Across most of central and eastern Ohio the unit is 100-150 ft. thick, but accumulations of up to 400 ft. are present in south-central Ohio. In central Ohio, which is the effective western limit of the Conasauga; the upper portion of the unit grades laterally into the Kerbel Formation (arenaceous dolomite).

Knox Dolomite - Lower Copper Ridge (informal unit)

The Lower Copper Ridge is contained within a 50-500 ft. thick interval across eastern Ohio, being thinnest in the northeast corner of the State and thickest in south-central Ohio. It is composed of a relatively pure micro- to finely crystalline dolomite with a minor clay content. Locally, portions may be sucrosic and have minor porosity, and the unit commonly makes connate water while drilling.

Knox Dolomite - Copper Ridge "B" Zone (informal unit)

The informally named Copper Ridge "B" ranges in thickness from about 200 ft. in the northeast corner of the State to about 75 ft. across the southern part of the State. Across most of its range the section comprised of argillaceous dolostones and gray shales; the basal portion may be arenaceous or contain shell fragments, suggesting possible deposition on an erosional surface. In central Ohio the unit truncates unconformably against the regional Knox unconformity. The "B" zone may be oil and gas production where the "B" zone is encountered within the subcrop zone and is contained in an erosional remnant. The "B" zone has also been productive in Knox County where hydrocarbon may be structurally trapped.

Knox Dolomite - Copper Ridge (informal unit)

The Copper Ridge is present across eastern Ohio as a 100-350 ft. thick unit that is composed of a relatively pure microcrystalline to finely crystalline dolomite with a minor clay content. The upper portion is arenaceous and transitional into the overlaying Rose Run sandstone. The Copper Ridge subcrops against the regional Knox unconformity in central Ohio. It may constitute an excellent oil and gas reservoir where the rock occurs in paleo-erosional remnants that underwent porosity enhancement due to subaerial exposure.

Knox Dolomite - Rose Run (informal unit)

The Rose Run is most widely recognized across eastern Ohio as a dolomite containing a series of readily identifiable interbedded sand bodies. It ranges from about 50-125 ft. in thickness. At its western edge the Rose Run subcrops unconformably against the regional Knox erosional surface. The Knox unconformity may exhibit positive relief that is vested in small (10-20 ac.) paleo-erosional remnants whose height is commonly on the order of 20-80 ft. Within its subcrop zone, Rose Run sands that are contained in the high-standing remnants were exposed to prolonged sub-aerial conditions that degraded the dolomitic cement in the sandstone, resulting in a substantial enhancement of porosity and permeability. Surrounded and/or overlain by younger impermeable Ordovician shale and limestone, such remnants became excellent oil and gas reservoirs. Below the grade of the Knox erosional surface or downdip from the subcrop, the porosity and permeability of the Rose Run is modest at best and, lacking any definable trapping mechanism, is barren of hydrocarbon except in the unusual circumstance of a closed structure.

Knox Dolomite - Beekmantown (informal unit)

In a manner similar to that of the underlying Rose Run sandstone, the Beekmantown is present across eastern Ohio and at it western edge is truncated against the regional Knox unconformity. This truncation occurs east of the AOR. The Beekmantown is a dense, white to light gray, micro- to very finely crystalline dolomite. Certain zone are especially prone to porosity development where the rock is contained within an erosional remnant; under those conditions it has been successfully exploited for gas production.

II.A.1.b ORDOVICIAN PERIOD

Wells Creek Formation

The Wells Creek Formation resides uncomformably on surface of the Knox Group. The formation is comprised three distinct lithologies, a lower dolomitic shale, an intermediate calcareous shale, and an upper limestone. These distinct, readily identified units give rise to considerable confusion as regards the nomenclature for the Wells Creek. In popular (i.e. oilfield) usage where most of the first hand exposure to the rocks occurs, the lower two lithologies may be collectively referred to as Glenwood, and the upper unit denoted as Gull River. Alternately only the lower unit gets the Glenwood notation and the middle unit may be identified as Lower Chazy.

Locally, the Wells Creek Formation has a total thickness of 100-120 ft., the thicker section being characteristic of a regional setting, and the thinner being associated with high-standing Rose Run erosional remnants.

Black River Group

The Black River Group was deposited on a stable, shallow, low-relief platform. It is about 750 ft. thick along the eastern edge of Ohio, thins to about 450 in central Ohio, and more or less maintains that thickness across the remainder of the State. Lithologically, it is predominantly a brown or dark gray-brown, dense, finely- to micro-crystalline limestone. The upper portion of the unit may contain one or more thin (to 4 ft.) bentonite beds, some of which are traceable across much of the State. The lowermost 50 ft. of the unit is argillaceous and contains some thin, black stringers of slightly calcareous shale.

Trenton Limestone

The Trenton Limestone is present across all of Ohio, ranging in thickness from about 300 ft. in the northwest part of the State to about 40 ft. in west-central Ohio. Depending on locale, it displays various shades of white, light to dark gray, and brown limestone, and is commonly fossiliferous. Clay and thick black shale may be included. Where fractured and subsequently dolomitized, it can be an excellent oil and gas reservoir, as was the case for the giant Findlay-Lima-Peru field in western Ohio and eastern Indiana.

Point Pleasant Formation

The discussion of the Point Pleasant Formation as presented herein will incorporate the overlying Utica Shale. Both are generically organic, basinal brown to black calcareous shales that are recognized chiefly for sourcing oil and gas from unconventional plays along the eastern edge of Ohio and sourcing hydrocarbon to a host of Cambrian-Silurian reservoirs in the Appalachian Basin. The Point Pleasant Formation is commonly fossiliferous at its base. The Utica has a gradational contact with the underlying Point Pleasant and the overlying Cincinnatian Group. They have a combined thickness of up to 240 ft. in the AOR.

Cincinnatian Group

The Cincinnatian is an approximately 500 ft. thick along the western margin of the State and about 2500 ft. thick along Ohio's southeastern border. In western Ohio the Cincinnatian Group is exposed at the surface as a series of thinly interlayered, fossiliferous gray shales and argillaceous limestones. In eastern Ohio, the few wells that are drilled deep enough to reach the Cincinnatian Group reveal a monotenous sequence of gray shale. Because it has no known commercial value, little attention has been paid to the unit and it remains poorly understood and poorly described.

Queenston Shale

The Queenston Shale is an approximately 400 ft. thick, red, silty shale indicative of an emergent landscape at the end of the Ordovician. It transitions downward into the Cincinnatian Group. The upper surface of the Queenston is erosional, and in certain locales it exhibits considerable relief, enough in instances to preclude deposition of the overlying Medina or even part of the Clinton sandstones. Having no commercial value, the Queenston is wireline logged infrequently, and even at that rarely given any scrutiny.

II.A.1.c SILURIAN PERIOD

Clinton Formation

The Ohio Geological Survey denotes the Clinton Formation in eastern Ohio as being comprised of the Medina Sand and the Clinton Sand, the latter of which can be divided into the distinctive White Clinton, and the Red Clinton (Shlucher, 2004). Elsewhere, this same section is identified as the Cataract Group which is comprised of the Medina Sandstone and the Clinton sandstone (Riley, et al).

Medina Sandstone

The Medina is a thin (<20 ft.), silty to fine-grained transgressive, quartz-cemented sandstone deposited on the Queenston erosional surface. Its range is limited to the eastern third of Ohio, and it thins westward to a pinchout. Its thickness may be influenced by the paleotopography of the underlying Queenston shale. In certain restricted areas the Medina is well developed with regard to porosity and permeability; and it may produce oil and gas where such sands can be encountered in an updip pinchout. Otherwise, in most areas the sand is too finely textured and lacks sufficient porosity to be considered reservoir rock.

Clinton Sandstone

The Clinton sandstone, by itself, is A a series of thin, overlapping and interfingered sand lenses encased in a fissile gray shale. The lower portion of the sandstone body is informally designated as the White Clinton, which in turn is overlain by the Red Clinton. The Clinton is upwardly regressive and fines upward. The shale above and below the sandstones proper is referred to as the Cabot Head Shale.

Dayton Formation

The Dayton Formation is identifiable across Ohio. It was deposited on the upper erosional surface of the Clinton Formation.as a series of thin transgressive, onlapping carbonate lenses; individual lenses may be 5-40 feet thick, and in the aggregate can be as thick as 60 ft. Additional evidence of the prevailing shallow water environment is given by the common appearance of a thin, deep red, hemitiic limestone oolite at its base. The common "Packer Shell" moniker for the Dayton Formation derives from century-ago cable tool drillers who used the dolomite bed(s) as a casing seat when drilling to the Clinton sandstone in eastern Ohio.

Rochester Shale

The thickness of the Rochester shale expands from about 100 ft. in the central portion of Ohio to about 300 ft. along the Ohio River on the southeastern border. The Rochester shale is a mix gray shale and dense, blocky, red and green marls, the latter occurring primarily in the lower half of the unit. Lockport Dolomite

Lockport Dolomite

The Lockport Dolomite, informally referred to as the Newburg, is an accumulation of carbonates that may range from dolomite to limestone, the dolomite mineralogy predominating. The Lockport Dolomite is notable for the small (commonly 10-100 ac.) fluid-bearing reefs contained within, these mainly in the northeastern part of the State. Drillers informally refer to these porous zones as the Newburg. Where such reefs are encountered, they typically produce copious amounts of water and, on occasion, some hydrogen sulfide gas; oil and gas is less commonly encountered. Because the reefs are very porous and highly permeable, they are not infrequently utilized as small-volume disposal reservoirs. In the extreme southern part of the State the Lockport contains what are interpreted as outliers of the north-south trending, gas productive Williamsport sandstone bar deposit. The Lockport is about 300 ft. thick across most of eastern Ohio, but thins to about 200 ft. in the northeastern corner of the State, and expands to about 350 ft. in southeastern Ohio.

Salina Group

The Salina Group ranges widely in thickness from about 300 ft. in western and central Ohio to about 1200 ft. along the Ohio River in southeast Ohio. It is composed of a predictable sequence of dolomite, anhydrite, and salt, and contains a minor amount of thin gray shale. In the eastern third of the State, salt is thick enough to be solution mined in northeastern Ohio and underground mined along the Lake Erie shoreline. Solution-mined caverns have been used for storage of natural gas liquids. The sal beds pinch out east of the Buckeye Brine facility in Coshocton Co.

II.A.1.d DEVONIAN PERIOD

Bass Island Dolomite

The 75 ft. thick Bass Island unit is the basal member of the Devonian sequence. It has a limestone-dominant lithology, and may contain purer thin (to 15 ft.) dolomite sections. The dolomite portions may be sucrosic and/or brecciated and may have minor porosity, but rarely yields any fluid It does not produce oil or gas within the AOR. It is bounded above and below by unconformities.

Helderberg Limestone

The Helderberg Limestone is bounded above and below by unconformities. Lithologically, it is similar to the underlying Bass Island Dolomite. Minor secondary porosity is ascribed to the basal portion of the unit

Oriskany Sandstone

Oriskany Sandstone is present in the eastern quarter of Ohio where it represents a distal tip of an easterly sourced sediment. It pinches out unconformably along its western edge. The Oriskany sandstone may have commercial value as a producer of gas and oil where entrapment is afforded by structure, lateral variations in porosity and permeability, or updip pinchout;.

Onondaga Limestone

The Onondaga Limestone sits uncomformably on the Oriskany Sandstone. The approximately 140 ft. thick unit was deposited on a stable platform that promoted the accumulation of a dense, very finely- to micro-crystalline limestone. Some chert is contained in the rock, especially eastward from the AOR. Informally referred to as the Big Lime, the sharp, easily identified top of the unit is a favored mapping horizon and an important marker bed for drillers.

Devonian Shales

As used herein, the Devonian Shale moniker is used to denote an approximately 1555 ft. thick section of shale between the Berea Sandstone and the Onondaga Limestone. It is comprised principally of the Hamilton Group, overlain by the Olentangy Shale, and subsequently by the Ohio Shale. The strata thicken eastward and reflect, initially, an actively subsiding foreland basin. Initially, dark gray to black shales (Hamilton Group) were deposited, followed by a thick sequence of gray shales (Olentangy Shale). The Ohio Shale is comosed of a black shale at its base, this in turn giving way to gray shale, and finally a dark brown-gray shale, reflecting increasingly shallow deposition.

Olentangy is composed of a series of gray and black shales, portions of which may be calcareous or include thin beds of limestone. Within the AOR and its vicinity, none of the black shales contained in the Olentangy have a high enough total organic carbon (TOC) content to warrant consideration as hydrocarbon reservoir, though they may have generated some hydrocarbon that found its way to other reservoirs above or below.

The Ohio shale as discussed herein includes, from bottom to top, the Huron, Chagrin, and Cleveland members. Except for portions of the Huron member that contains some low TOC black shale, the interval is composed of gray shale that grades to a brown-gray or brown-black near the top.

Bedford Shale and Berea Sandstone

The silty nature of the Bedford Shale suggests that it is transitional to the overlying Berea sandstone. Neither is prominent in Coshocton County, each unit being about 20 ft. thick within the AOR.. where it is exposed at the surface and mined as building stone. The Berea Sandstone is composed of a silty, very fine-grained, mechanically cemented pale brown to gray sandstone.

II.A.1.e MISSISSIPPIAN PERIOD

Sunbury Shale

Referred to by cable tool drillers as the "Coffee shale" for its distinctively rich brown color, the 0-40 ft. thick Sunbury shale is organic, slightly silty, and breaks easily under the drill. Although it does not produce oil or gas by itself, it is thought to be a source for the oil and gas trapped in the underlying Berea sandstone. Its range is the eastern third of Ohio

Cuyahoga Formation

Locally the approximately 150 ft. thick Cuyahoga is composed entirely of non-porous, non-permeable gray shale. Elsewhere in the State, particularly to the southeast, the unit may be silty in part, or even contain distinct and identifiable siltstones that are capable of delivering marginal quantities of oil and gas.

II.A.1.f UNDIFFERENTIATED MISSISSIPPIAN AND PENNSYLVANIAN CLASTICS

In eastern Ohio the Mississippian and Pennsylvanian section above the Cuyahoga shale is comprised of alternating layers of shale, siltstone, and sandstone, and thin beds of limestone that resulted from small but rapid fluctuations in depth of burial. Cut-and-fill features abound. The Pennsylvanian contains multiple thin beds of mineable coal. Being the youngest and shallowest sediments in eastern Ohio, they were among the earliest developed for oil and gas production. Their heyday had passed by the time wireline logging was introduced to the Appalachian Basin, and good wireline coverage over these units is thin. Most of the good detailing of the Mississippian and Pennsylvanian rocks has been an outgrowth of mapping associated coal beds.

II.A.2 - CHARACTERISTICS OF THE INJECTION AND CONFINING ZONE

II.A.2.a - CHARACTERISTICS OF THE INJECTION ZONE

The Buckeye Brine No. 4 Adams is to be completed openhole. The injection interval is considered that portion of the wellbore below the intermediate hole casing seat. That casing is programmed to be set near the base of the Rose Run at a depth of approximately 6070 ft. Accordingly, the injection interval includes, Knox Groups (Rose Run and Copper Ridge sub-units), Conasauga Formation, and the Rome Formation.

The total depth in the No. 4 Adams is projected to be about 7000 ft., this penetrating approximately 465 ft. of the Rome Formation, and being about 185 ft. above the Mt. Simon sandstone. The thickness of the injection interval from the base of the casing liner to total depth is estimated to be 930 ft.

The discussion that follows presents the general characteristics of each unit. So as to not distract the dialogue with details of possible lithology changes across the breadth of the State, these comments are generally meant to imply a 25-miles radius beyond the Area of Review (AOR), unless otherwise noted.

Approximately 25 miles to the west, the thickness of the upper portion of the Copper Ridge is reduced by erosion against the regional Knox unconformity. Elsewhere, north and south, and to the east, the Copper Ridge is laterally continuous and is of more or less predictable, if not constant, character. The upper portion of the Copper Ridge is arenaceous and may produce oil and gas in its subcrop zone to the west. The lower portion of the Copper Ridge has little or no porosity and gives no evidence of permeability.

As an informal middle sub-unit, the Copper Ridge "B" is distinctive on openhole wireline logs for its high gamma-ray signature due to included clay and shale content. Neutron porosity may read up to 14%, though some or much of that may be attributed to bound water and the presence of clay in the rock. Nonetheless, spinner and radioactive tracer (RAT) tests, as well as temperature logs, have suggested some measure of fluid movement in and out of the unit.

The basal part of the Knox Group, the informal Lower Copper Ridge, is encountered as a massive, clean dolomite, and is easily recognized in Coshocton and adjacent Counties. The upper portion ~~of the LCR~~ is commonly sucrosic and well logs may indicate some manner of porosity. During drilling, the unit commonly gives up at least some measure of fluid, validating observations of texture in the cuttings and values generated by the well logs. Neutron porosity is typically a good indicator of permeability. Injection testing has shown temperature kicks (cooling) and RAT intake across from the approximately 30 ft. of >8%-neutron porosity in the lowermost 125 ft .of the LCR.

The Conasauga Formation is a sequence of interbedded dolomite, argillaceous dolomite, and shale across most of eastern Ohio. The upper part of the Conasauga Formation is a dense, argillaceous dolomite that is not considered to have reservoir potential. Within the lower third of the unit, a 2-ft. thin sandstone is present and other portions are arenaceous. RAT tests suggest fluid movement across the entirety of the Conasauga Formation, and spinner tests have indicated multiple points of fluid intake. Temperature logs have shown cooling across basal section of the unit. There are not enough wide-ranging penetrations and testing to determine the lateral extent of reservoir conditions in the basal Conasauga Formation.

The Rome Formation, excepting an arenaceous basal section, is a massive, micro- to finely crystalline dolomite. The basal portion of the unit is upwardly transitional from the underlying Mt. Simon sandstone and has an upwardly decreasing sand content. The upper portion of the Rome may be sucrosic in part. Porosity development may be poor to excellent, but is invariably subtle, and not easily or accurately quantified with wireline logs. The best porosity is developed within the uppermost 100 ft. of the unit and is believed to be linked to an end-of-Rome Formation erosional surface and associated karsting.

II.A.2.b - CHARACTERISTICS OF THE CONFINING ZONE

The Buckeye Brine No. 4 Adams is to be completed openhole. The casing is programmed to be set to the base of the Rose Run Sandstone at a depth of approximately 6070 ft. The confining zone is considered that portion of the wellbore above the production casing seat. The purpose of the confining layer is to insure protection of shallower zones that are capable of providing potable water. A competent confining zone must be laterally continuous, and free of fractures and faulting that would permit vertical migration of injected fluids. A portion of the confining layer must be sufficiently plastic to accommodate unforeseen stresses without allowing passage of fluids.

The discussion that follows presents the general characteristics of each unit. So as to not distract the dialogue with details of possible lithology changes across the breadth of the State, these comments are generally meant to imply a 25-miles radius beyond the Area of Review (AOR). The thicknesses cited in this section reflect the norm within the AOR. It should be kept in mind that all of the referenced formations thicken slightly to the east, and similarly thin to the west.

Within the Area of Review (AOR) the confining zone is approximately 2270 ft. thick and consists of approximately 105 ft. of the Knox Group (Rose Run), 770 ft. of Ordovician limestone and calcareous shale, and 1395 ft. ft. of Ordovician shale.

The Rose Run Sandstone (Fig. II.B.6.b.01)*, where fully represented within the AOR, is about 100 ft. thick. However, locally it is truncated against a regional unconformity surface so that only two-thirds of that thickness is commonly present. Small (to 20 acres), isolated erosional remnants that are encased laterally and overhead by the impermeable Wells Creek Formation, may be host to accumulations of oil and gas. Porosity within these remnants was likely enhanced by subaerial exposure to 10-15 percent. Away from the setting of an erosional remnant, the Rose Run lacks a lateral seal and does not contain oil & gas. That portion of the Rose Run that resides below the unconformity was denied the enhancement to porosity; there it is a relatively poor conductor of fluids, having porosity that rarely exceeds 10 percent. Openhole injection testing performed on the adjacent Buckeye Brine No. 1 Adams indicated that no fluid was entering the Rose Run Sandstone.

The Wells Creek Formation is composed of dense, extremely non-porous, non-permeable rock with excellent lateral continuity. The Wells Creek Formation ranges from a distinctive pale green, argillaceous dolomite with included shale to a dense micritic limestone. The Wells Creek Formation provides the seal against upward oil and gas from the underlying Rose Run

The combined Black River Group and Trenton Limestone sections are 650. ft thick. The Black River Group (Fig. II.B.6.b.02)* is a massive, uniformly dense, non-porous, non-permeable, micro- to very finely crystalline limestone, not unlike the underlying. Wells Creek Formation. The upper portion of the unit may contain one or more thin (to 4 ft.) bentonite beds, some of which are traceable across much of the State. The lowermost 50 ft. of the unit is argillaceous and contains some thin, black stringers of slightly calcareous shale. Lateral continuity is excellent. The approximately 55-ft. thick Trenton limestone is composed of a very fine to coarsely crystalline limestone, and is abundantly fossiliferous at the top, becoming less so toward the bottom. Portions of the unit may be argillaceous or contain very thin stringers of black shale. Lateral continuity is good, any variations being vested primarily in very minor thickness changes.

The Point Pleasant Formation (Fig. II.B.6.b.03)* is generically considered organic black shale. Within the AOR it has a combined thickness of about 240 ft. Its specific lithologies range from argillaceous limestone to calcareous and organic shale.. Fossil shell beds may be present, particularly near the base of the Point Pleasant. The Point Pleasant is considered impermeable.

The Cincinnatian Group is an approximately 755 ft. thick section of gray shale. Because few wells are drilled deep enough to reach the Cincinnatian and because it has no known commercial value, little attention has been paid to the unit. It remains poorly understood and poorly described. Where the Cincinnatian has been reached by the drill, it yields no shows of any kind and is thus regarded as impermeable and barren of fluids. Lateral continuity is excellent.

The Queenston is an approximately 400 ft. thick red, silty shale. The boundary between the Queenston and the underlying Cincinnatian is transitional.. Having no commercial value, the Queenston is rarely given more than a cursory look, but based on drilling observations, it is considered to be an impermeable, non-reservoir rock.

** The illustrated sections are derived from the openhole wireline images for the offsetting Buckeye Brine No. 3 Adams due to its more comprehensive log suite.*

II.A.3 - REGIONAL CROSS-SECTIONS

Using wireline log data from wells that were drilled into the injection interval within an approximately 25-mile radius of the AOR, a north-south and a west-east cross-section were constructed for the purpose of determining how the AOR itself fit into the wider geologic picture.

Using wireline log data from wells that were drilled into the injection interval within an approximately 25-mile radius of the Area of Review (AOR), a north-south and a west-east cross section (Fig. II.A.3.01) were constructed for the purpose of determining how the AOR itself fit into the wider geologic picture.

Two versions of each section are presented. The structural section uses a sea level datum. The stratigraphic section uses a top-of-Trenton datum.

The west-east structure section (Fig. II.A.3.03) shows the expected southeastward dip, though any thickening into the Appalachian Basin is less evident. The north-south structural section (Fig. II.A.3.02) is less straight forward because it crosses back and forth over regional strike lines. It shows an increase in the rate of dip in the center of the section, and highlights the structural discrepancy between the Buckeye No. 1 and No. 3 Adams wells.

The west-east stratigraphic section (Fig. II.A.3.05) shows a modest amount of eastward dip and some mild thickening of the individual units, as would be expected. It also illustrates the truncation of the Knox sediments (Beekmantown, Rose Run, and Copper Ridge) against the Knox erosional surface. The north-south stratigraphic section (Fig. II.A.3.04) shows a general thickening of the individual units to the south.

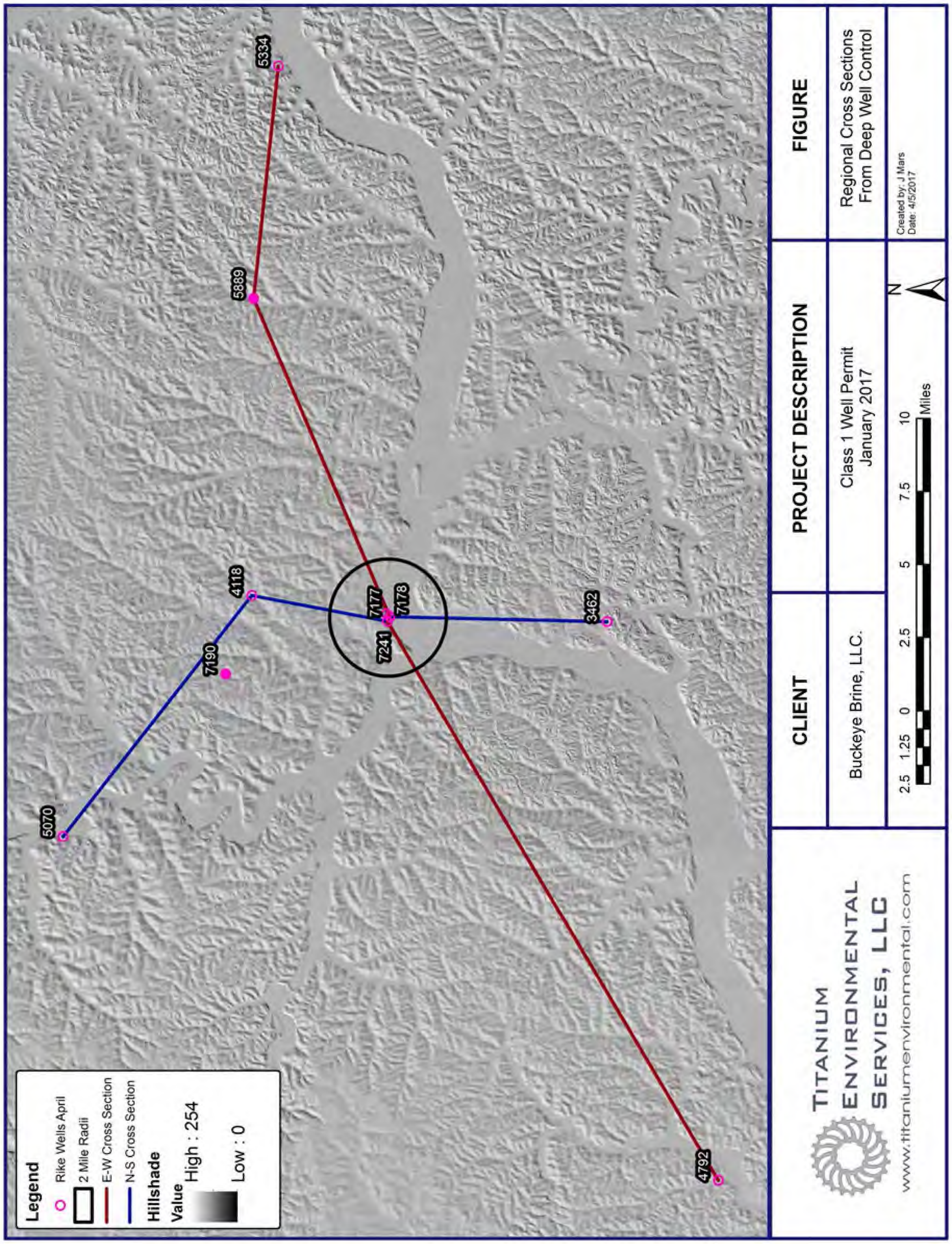


Figure II.A.3.01 - Map showing the lies of structural and stratigraphic cross-sections

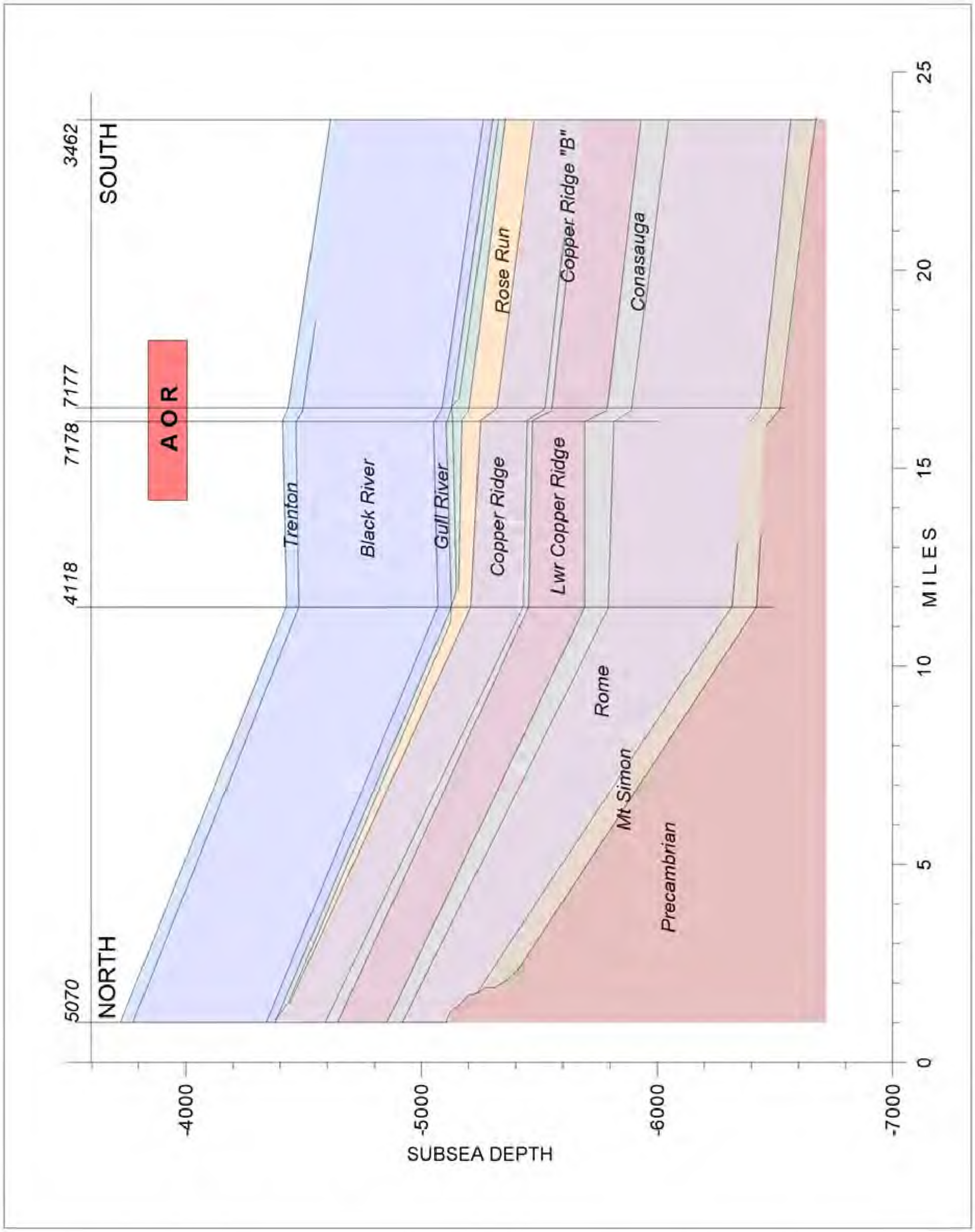


Figure II.A.3.02 North-South structural section traversing the Area of Review and passing through the Buckeye Brine facility

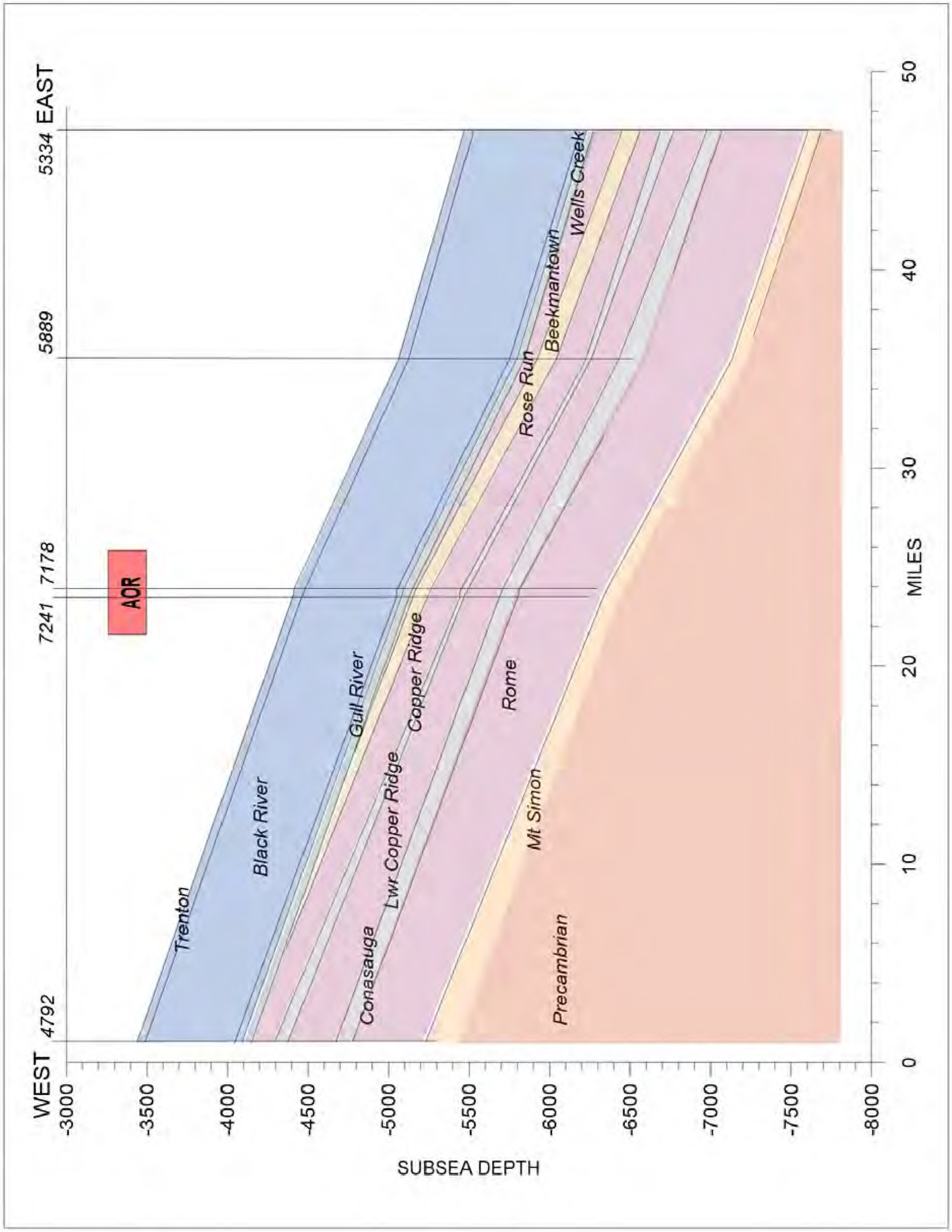


Figure II.A.3.03 West-East structural section traversing the Area of Review and passing through the Buckeye Brine facility

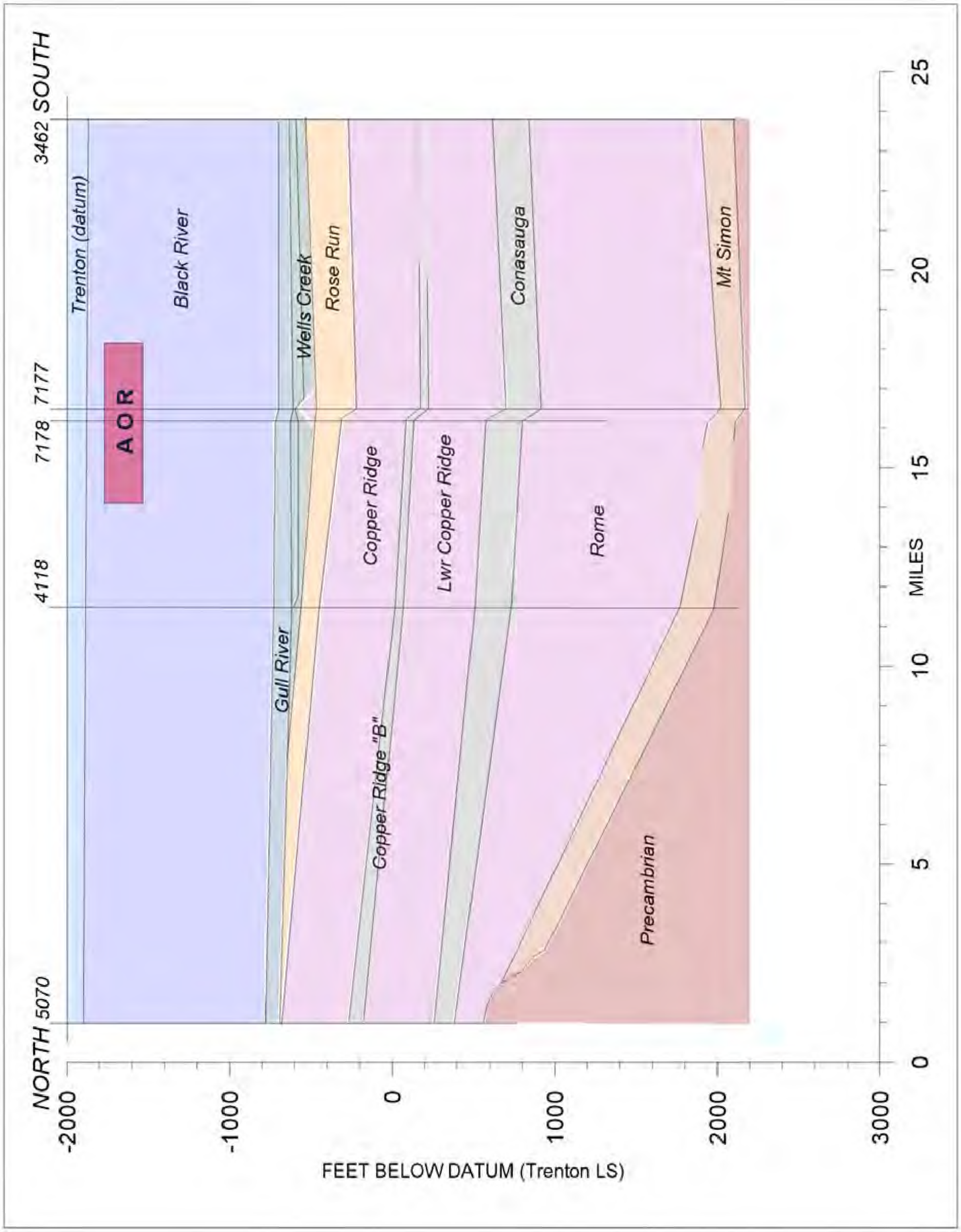


Figure II.A.3.04 North-South stratigraphic section traversing the Area of Review and passing through the Buckeye Brine facility

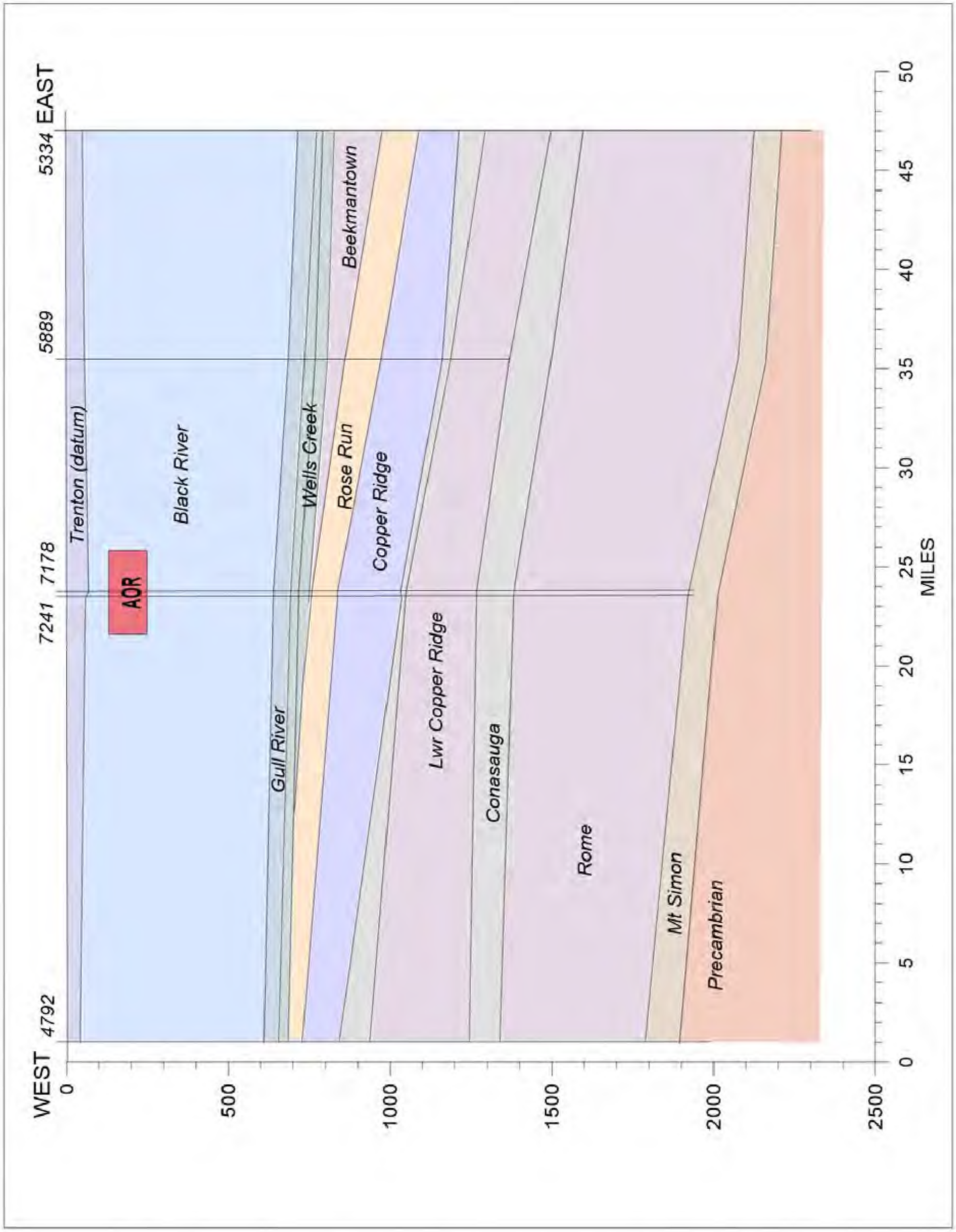


Figure II.A.3.05 West-East stratigraphic section traversing the Area of Review and passing through the Buckeye Brine facility

II.A.4 REGIONAL STRUCTURAL GEOLOGY

Regional Influences

The Precambrian complex of igneous and metamorphic rocks upon which the Paleozoic sedimentary section was deposited in eastern Ohio is part of the larger Grenville Province. The Province is the eastern component (current day bearings) of the mountain building and subsequent rifting system that resulted from the collision between the ancient continents of Laurentia and Amazonia along a line that ran from Nova Scotia to Mexico. Following the mountain building, an expansive period of erosion ensued that is estimated to have lasted 400-600 million years and reduced the Precambrian complex to a broad, irregularly eroded surface with relief of up to 300 ft. (Hansen, 1998).

The Grenville Province extends eastward across Ohio and the Rome Trough and is exposed in the Blue Ridge massifs. The trough is the core of the Appalachian Basin. A down-to-the-west master fault on the southeast edge of the trough is termed the East Margin Fault. It is complemented along the northwest edge of the trough defined by four or five closely spaced normal faults that step eastward into the basin. Fault timing within the trough is attributed to Early Cambrian to Middle Ordovician. Few of the faults show penetration any higher than the Trenton limestone. Nearly all of the faults show reactivation involving both tension and compression. Nearly 20,000 ft. of Paleozoic sediment has accumulated in the Rome Trough (Schumaker, 1996).

Structure on the Ohio Platform

The Ohio Platform portion of the Grenville Province encompasses the area of central and eastern Ohio. It received sediments, both clastic and carbonate, throughout the Paleozoic. On a local scale, the strata in eastern Ohio seem relatively flat and of uniform thickness. In a broader view, the various units can be seen to thicken to the east, evidence that the Ohio Platform was gently subsiding into the Appalachian Basin throughout the Paleozoic (Fig. II.A.4.01). The Precambrian surface sits at about (-2500 ft.) in central Ohio, and dips continuously eastward to a depth of about (-13,000 ft.) along the southeast edge of the State (Baranoski, 2013). The Ohio Platform has few significant structural features (Figures II.A.4.01 and II.A.4.02).

The Cincinnati arch is a broad uplift that separates the Illinois basin on the west from the western limb of the Appalachian Basin. The arch emanates in Tennessee and passes through Kentucky and into southern Ohio before splitting in two. The west limb, the Kankakee Arch, veers sharply into Indiana. The apparent northern continuation of the Cincinnati Arch is termed the Findlay Arch, though the former term is frequently used as a convenience. The evolution of the arch took place from Late Ordovician through Late Paleozoic and was accompanied by the creation of an extensive fault set along its axis in northern Ohio. The more eastern portion of the Ohio Platform was essentially untouched by this activity.

The Waverly Arch (Woodward, 1961) trends north-south through central Ohio. Defined less on the basis of structure and more on marked changes in stratigraphy and topography, it is generally conceded to divide two separate Cambrian depositional regimes, one to the east being carbonate dominant, and the one to the west having a greater infusion of clastics. Upper Paleozoic strata also show effects of the arch.

The Akron-Suffield-Smith (ASS) fault system is a 30-mile long set of basement-seated, en-echelon right lateral faults that trend west-northwest through Portage Co. in northeast Ohio. Some ancillary normal fault displacement is ascribed to portions of the trend. The fault set is defined by well control and reconnaissance seismic that was attendant to oil and gas exploration. The ASS fault system is commonly discussed in conjunction with the similarly oriented Highlandtown fault that transects Carroll and Columbiana Cos. and is about 10 miles east of the ASS system. The Highlandtown has the same orientation as the ASS, but is offset to the south about 15 miles. Like the ASS fault system, the Highlandtown is a right lateral fault with up to 200 ft. of displacement on the Precambrian surface.

The Killbuck Dome in southern Holmes Co. is 15 miles north-northwest of the AOR in Coshocton Co. The dome is compact, contained in an area about 5 miles west-east and 3 miles north-south, and is transected by a series of randomly oriented faults whose history includes compression and tension. Movement occurred from the Precambrian to at least the Mississippian, though the most intense movement happened before the onset of Paleozoic sedimentation. Relief on the Precambrian surface was up to 300 ft. and in places precluded deposition of the Mt. Simon sandstone and part of the overlying Rome dolomite. Movement slowed substantially after about Middle Cambrian, such that sedimentation accommodated that movement without observable faulting or fracturing.

The Cambridge Arch, or Cambridge Cross-Strike Discontinuity, is a debated feature with a north-south trend that is located in southern Ohio. Although the Cambridge arch has been recognized via shallow structures for over a hundred years, it was not until the wider availability of wireline logs in deeper wells that geologists had a means of looking at the underpinnings of the structure. Previous authors long wrote of the arch, but Calvert (1987) discussed and illustrated what is likely the most accepted model, that of a late basement-seated, eastward dipping thrust fault that also incorporated one or more decollement layers moving westward across Silurian salt beds. A less accepted theory is that the arch is the product of a strike-slip fault zone. The arch is most distinctly seen in shallow (Mississippian and younger) sediments where it appears as an unmistakable anticline along its length. Originating near the Ohio River in southern Ohio, the arch appears as a parallel northern extension of the Burning Springs anticline, the two possibly connected by a series of transform faults. The effect and character of the arch diminishes northward such that its northern terminus is also much debated.

The preceding notwithstanding, geologists remain uncertain about the Cambridge Arch. Depending on the map, it may be drawn in with a solid, certain line, or a dashed line indicating a tenuous thought. Some maps omit it.

In Coshocton Co. the Cambridge Arch is commonly drawn with a dashed line, and the line is usually terminated about midway north through the County. In southern Coshocton Co. the arch has been related to what is interpreted on the CO-CORP regional seismic line as a basement fault. A short distance north, in the vicinity of the AOR, there does not appear to be sufficient evidence to sustain the notion of direct, proximal basement influence.

That is not to imply that there is no evidence of the arch as at least a shallow structural phenomenon. Shallow mapping on the Berea sandstone in the AOR (Fig. II.A.4.03) shows an anticline with about 65 ft. of relief approximately 3 miles east of the Buckeye facility. Elsewhere to the south on this same structure where oil is produced from the Berea, local relief on the unit may be as much as 140 ft.

Berea, Onondaga (Big Lime), and Packer Shell maps by the Ohio Geological Survey (Digital map series PG-5) similarly portray a mix of structural possibilities. The Berea map is definitive in portraying at least a shallow structure in the form of an anticline east of the AOR, but shows that the arch is diminished or faded-out a short distance northeast of the Buckeye facility. The intermediate-depth Onondaga map does not indicate meaningful structure east of the AOR, but the deeper Packer Shell shows a tightening of the structure contours more or less on trend with the Cambridge Arch, suggesting some manner of possible basement disruption.

On the basis of local and regional subsurface structure mapping, and other researchers' seeming uncertainty regarding the exact nature Cambridge Arch in Coshocton Co., it is surmised that in fact a direct, local basement influence of the Cambridge Arch near the AOR is absent or minimal. It is likely that the Berea structure east of the AOR is a decollement on the Silurian salt whose impetus is a lingering, distal thrust from detached post-salt sediments to the east.

A prominent surface lineament that passes close by the city of Coshocton was originally referred to as the Coshocton Fracture Zone, and subsequent references have referred to it as the Coshocton Fault Zone. The control for the lineament was originally built from a USGS digital elevation model files (Mason, 1999) and is visible on the Ohio Geological Survey's shaded elevation map (Fig. II.A.4.04). Attributed to surface fractures, it is speculated to be associated with deep-seated fracture systems. It remains poorly understood and is omitted from most maps that portray regional or semi-regional structure.

In reporting on the extensively researched Ohio Geological Survey No. 1 CO2 stratigraphic test, 20 miles east of the Buckeye facility, it was reported that no regional extensive, deep-seated faults were identified within 25 miles of the test site (Wickstrom, et al., 2011).

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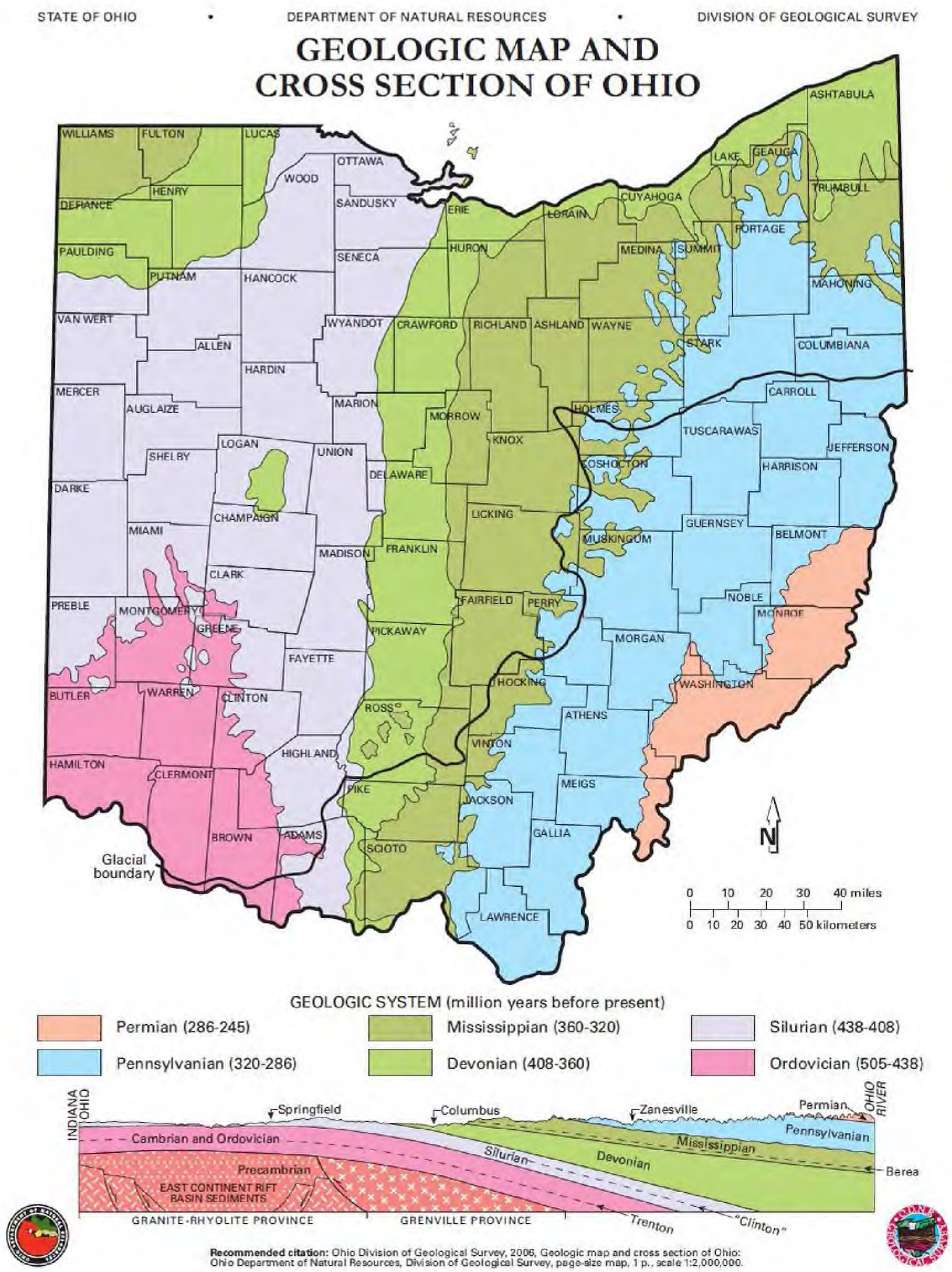

Figure II.A.4.01 Ohio Geological Survey map showing the axis of the Cincinnati Arch in western Ohio (Ordovician and Silurian outcrops). The cross section illustrates eastward dip and the thickening of strata in eastern Ohio.

Figure II.A.4.02 Map showing key structural features on and bordering the Ohio Platform

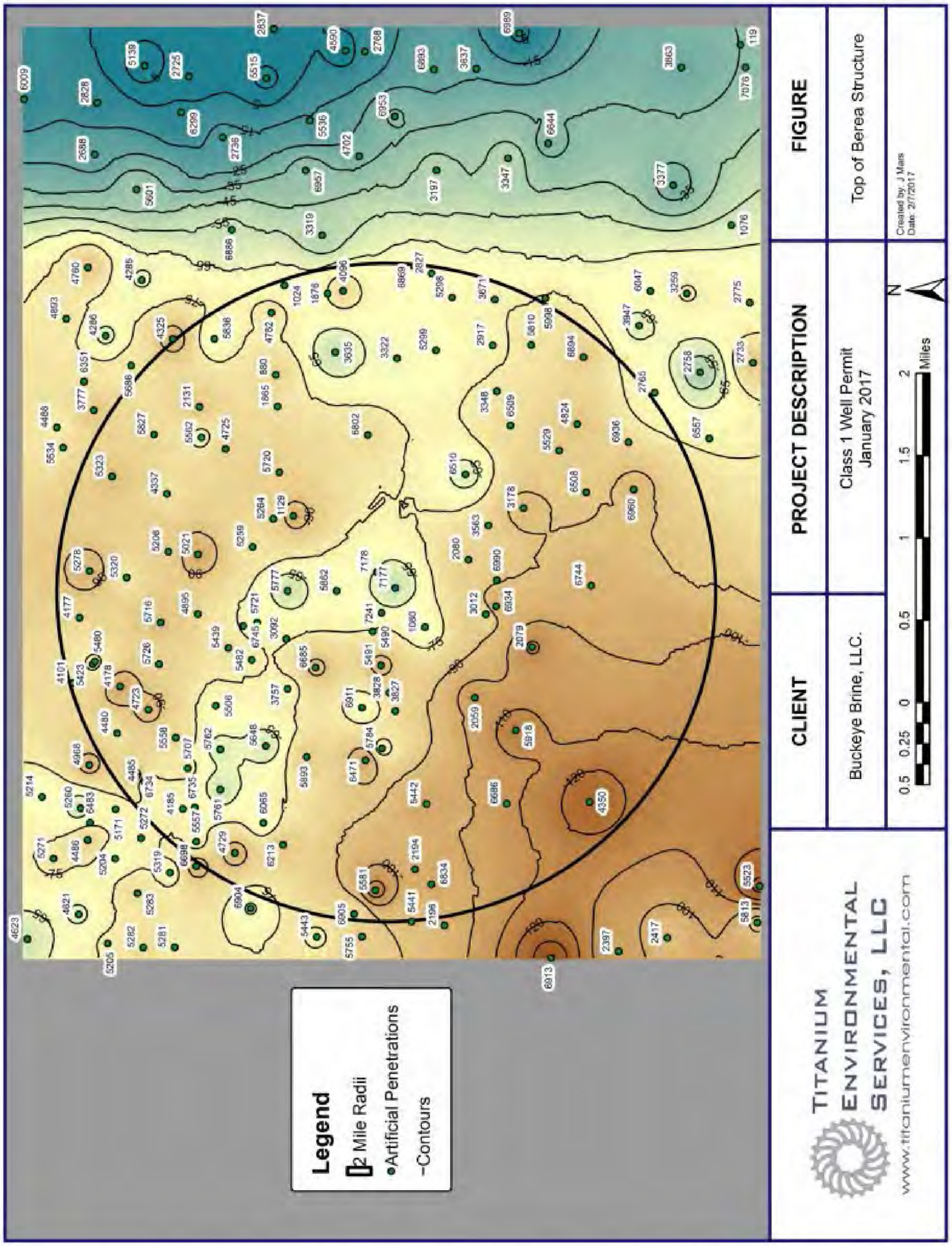

Figure II.A.4.03 - Structure map showing the manifestation of the Cambridge Arch on the top of the Berea sandstone outside the two-mile radius of the Area of Review.

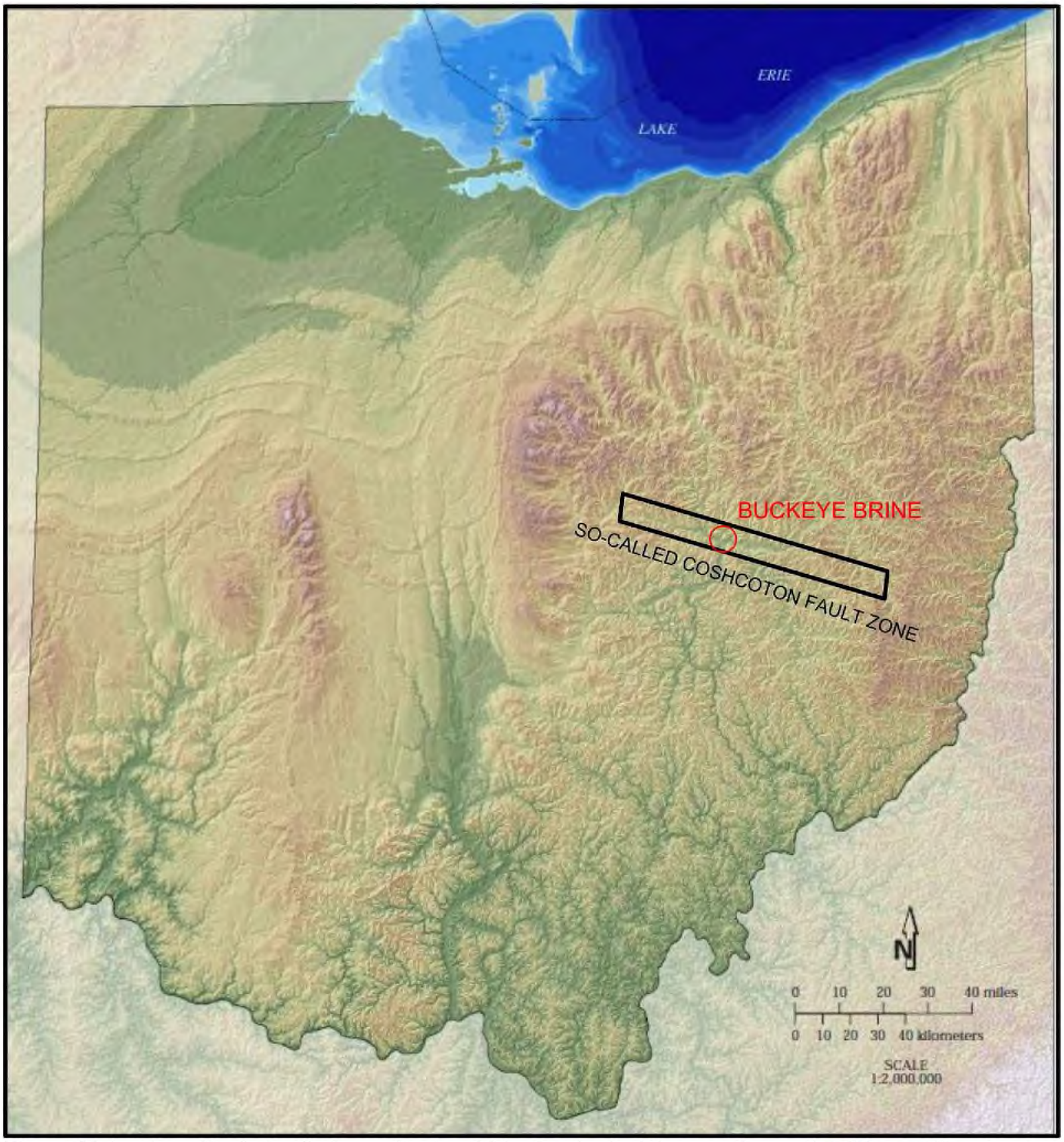

Figure II.A.4.04 - Shaded relief map by the Ohio Geological Survey shows the faint surface trace that is the basis for the Coshocton Fault Zone.

II.A.5 REGIONAL SEISMIC ACTIVITY

For over 200 years of recorded history, Ohio has felt the effects of earthquakes occurring outside its boundaries. In Ohio these events have registered as mild ground tremors to physical damage, as was the case for the 1812 New Madrid, Missouri series of earthquakes that damaged buildings in Cincinnati.

Within Ohio, there are certain areas of the State that have historically been shown to be more earthquake-prone (Fig. II.A.5.01).

A series of small and larger earthquakes that spanned more than a century in and around Anna, in western Ohio, culminated in a 1937 event that is recorded as having been a 5.4 magnitude (Richter) event. It caused extensive damage that ranged from fixable to ruinous. The most recent event was a 2.6 event recorded in 2008.

Over 100 events have been recorded in northeastern Ohio, most concentrated near the Lake Erie shoreline, with about 25 of those actually occurring in the lake, not far from shore. A 1986 magnitude 5.0 event in Lake Co. was attributed to an injection well that was eventually plugged and abandoned because of the association. However, the frequency of seismic events has continued, underscoring the inherent crustal instability in that area. Most of the earthquakes in the last 30 years have been magnitude 2.0-3.0.

About 30 small (<3.9 Richter) earthquakes are to have taken place in southern Ohio. As a group, these are widely scattered and most predate instrumented recordings.

With the onset of drilling deep Point Pleasant and Marcellus shale wells in eastern Ohio and western Pennsylvania, there have been occasional incidents of induced seismicity in connection with the very high-pressured stimulation treatments used in the wells. Such events may range up to magnitude 4.

Central and east-central Ohio have, for the most part, been without naturally-occurring seismic events.

Figure II.A.5.01 - Map showing earthquake epicenters in Ohio and adjacent areas (from Ohio Div. Geological Survey Environmental Series maps BG-2 and OhioSeis Network, 2012)

II.B LOCAL GEOLOGY

II.B.1. LOCAL PHYSIOGRAPHY AND BEDROCK

II.B.1.a. PHYSIOGRAPHY

Buckeye Brine's facility is 2 miles north of the city of Coshocton, and 0.6 miles north of the Tuscarawas River. Downstream from the facility, the smaller Walhonding River joins the Tuscarawas River on the north side of Coshocton where the two form the Muskingum River.

North of Coshocton, the local land surface is dominated by a flat, mile-wide incised valley that contains the meandering Tuscarawas River. Near the Buckeye facility, the river is at an elevation of 740 ft. The valley and the lower slopes of the adjacent hillsides are cut into the Pennsylvanian Pottsville Group, and the hillsides themselves are topped with nearly a full section of Allegheny Group. On the north and south sides of the river, tributaries tend to be short. Lamborn (1954) described these tributaries as immature.

II.B.1.b BEDROCK GEOLOGY

The Tuscarawas River has been incised into the Pennsylvanian Allegheny and Pottsville Groups, which have a combined thickness of about 300 ft. Total relief on the local topography is approximately 270 ft.

The hilltops on either side of the Tuscarawas River are topped with a nearly full section (140 ft. out of 150 ft.) of Pennsylvanian Allegheny shales, siltstones, and clays. The unit also includes Clarion, Kittanning, and Freeport coals. The Middle Kittanning has been mined from the surface and subsurface north of the Buckeye facility.

The river is cut into the Pottsville, and that same series of sediments form the bases of hills that border the valley. The lithology of the Pottsville is similar to that of the overlying Allegheny, both presenting a series of cyclothems. Above the valley floor, the Pottsville exposes the Brookville, Tionesta, Bedford, and Mercer coals, none of which have been mined locally.

An estimated 150 ft. of detritus and glacial outwash fill the valley floor, not counting the aforementioned terraces. On this basis, it may be surmised that the river at one time had cut into Mississippian sediments.

Reference cited:

Lamborn, R., 1954, Geology of Coshocton County: Ohio Division of Geological Survey, 245 p. Plus Map.

II.B.2 LOCAL GLACIATON

Neither the Wisconsin nor Illinoian ice sheets advanced far enough south and east through Ohio to impinge on the AOR. In like manner, there is no evidence that either of those glacial events had a meaningful effect on pre-Wisconsin/Illinoian drainage patterns.

Meltwater from both events emplaced substantial outwash deposits in the Tuscarawas River Valley as far east as Newcomerstown, 10 miles east of the AOR. The most visible of these deposits form broad, 20-60 ft. high terraces on either side of the river, and the less obvious deposits constitute the mile-broad, flat expanse of riverbed fill material.

Any possible evidence of the earlier Kansan or Nebraskan ice ages in eastern Coshocton Co. is generally considered too suspect to support declarative statements as to their character and effect.

II.B.3 - GROUNDWATER RESOURCES AND LOWEST USDW

The deepest underground source of drinking water (USDW) is defined (<10,000 ppm TDS) by the U.S. EPA. In the Coshocton area and the Area of Review (AOR) this is based on work done by Vogel (1982), which cited the Black Hand sandstone as the base of the USDW. Matchen (2006), however, mapped the Black Hand as an elongated sand body trending north-south and lying about 10 miles west of the (AOR). This throws into question the precise stratigraphic identification of the USDW reservoir. Nonetheless, as later mapped by Riley (2012), the so-called Black Hand is again cited as the deepest USDW and is shown to cover much of eastern Ohio. In the area of review, Riley's base of USDW lies at a depth of about 330 ft. from the surface (Fig. II.B.3.a-01 and Fig. II.B.3.a-02).

The depth to the USDW notwithstanding, culture in the AOR is largely confined to the valleys, where local domestic water is supplied chiefly by shallow domestic wells drilled into the glacial sand and gravel that fills the Tuscarawas River valley. Typically these wells are drilled and cased to a depth of 50-75 ft. and generate excellent yields that average about 35 gallons per minute (gpm). On its map "Yields of the Unconsolidated Aquifers of Ohio," the Ohio Division of Water Resources attributes these valley-drilled wells with potentials in excess of 500 gpm. Static water levels are about 25 ft. below grade. Although a few wells have been drilled to depths of over 100 ft., their yields and static levels are comparable to those of the shallower wells.

On higher ground, away from the valley, water may be obtained from perched sandstone aquifers contained within the Allegheny Group sediments. Yields and static levels are reported as being comparable to those encountered from the sands and gravel in the river valley.

Karst features, limestone formations with large open pores or caverns that can store or transport fresh water, are found primarily in Devonian and older rocks in western Ohio where limestone constitutes a significant portion of the bedrock. As such, Coshocton Co. is largely removed from consideration when discussing karst features. Within all of Coshocton County and the AOR there are no verified fractured limestone or karst features that can source fresh water, though an Ohio Geological Survey interactive map notes two suspected/unverified karsts in the county (Fig. V.B.3.a-

01). Elsewhere, the Ohio Geological Survey "Known and Probable Karst in Ohio, 2007" Map EG-1 denotes Coshocton Co. as "an area not known to contain karst features." Keeping in mind that the bulk of the geologic records that might illuminate the nature of the USDW are vested in wells drilled only into the river gravels and sands, but not through, and secondarily in wells drilled into perched clastic aquifers in the hills surrounding the river valleys; data for mapping carbonate reservoirs is practically absent. The best glimpse of the limestone bedrock is afforded in outcrop descriptions by Lamborn (1954); though he does cite one limestone outcrop that measures 5 ft. in thickness, nearly all of the limestone identified in surface outcrops in Coshocton Co. is less than 18 inches thick.

To a lesser degree, Coshocton municipal water is supplied to certain larger public and private facilities such as the Coshocton Co. Regional Airport, the Coshocton Christian Tabernacle church, and retail establishments close by Rt. 36.

Drilling and completion records for domestic wells are maintained by the Ohio Division of Water and are available online. The most recently drilled wells are represented by the most complete and accurate records. Wells that predate permit requirements may or may not be represented by a driller's record. Instances of more than one well using the same well identification number are common All known wells have been attributed with geographic co-ordinates.

Other than nominal descriptors such as "sandstone," or "gravel," the unconsolidated reservoirs are undifferentiated, either in the formally submitted water well records or published literature. Similarly, there has been insufficient subsurface work done to authoritatively differentiate the several sandstone and siltstone reservoirs that are tapped above the Tuscarawas River valley. For these reasons it is not possible to confidently construct piezometric maps for the various units.

In a broader, more regional setting, the AOR is contained within the Tuscarawas River Valley drainage basin. The United States Geological Survey (USGS) discussed subsurface water flow in the vicinity of the AOR in its "Summary of Hydrologic Data for the Tuscarawas River Basin, Ohio, with an Annotated Bibliography (2010-2015)." After recounting the availability of water well records from the Ohio Dept. Natural Resources Division of Water, and recorded water levels in domestic well contained therein, the USGS made the following observations:

1. Ground water flow is generally from the upland bedrock areas down into the sand- and gravel-filled valleys (general flow directions can be inferred by drawing flow lines perpendicular to surface contours anywhere on the map (Figure II.B.3.a.03).
2. The water-level surface mimics topography and generally follows surface-water flow directions. Topographic contours were used to refine (but not define) the contouring of the water-level elevations encountered in drilled wells, so this characteristic may be an artifact of the manner in which the contours were drawn.
3. In several areas data were too sparse to develop a water-level surface.

The findings of the USGS adhere to the commonly accepted observations that water levels, and by extension, water flow, follow the surface contour of the land. As applied to the vicinity of the Buckeye Brine facility, a large portion of the local groundwater will flow east to west through the

Tuscarawas River valley itself, this mostly south of the facility. A lesser amount of water will be derived from the higher ground north of the facility, the water moving in a south to south-southwest direction before mixing with the water in the river valley sediments and from there proceeding westward. With specific reference to the Buckeye Brine facility, subsurface water movement across the property will be primarily in a south-southwest direction (Figure II.B.3.a.04). Actual land surface profiles in the vicinity of the facility are illustrated in Figure II.B.3.a.05 and indicate the south and southwest components to be the primary contributors to determining the direction of ground water flow.

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Riley, R. A., 2012, Map EG-6, Elevation contours on the base of the deepest underground sources of drinking water in Ohio: Columbus, Ohio Department of natural Resources, Division of Geological Survey, 1 map (scale 1:500,000).

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Vogel, D. A., 1982, Salt/fresh water interface, ground-water mapping project - Final report to U.I.C. Program: Columbus, Ohio Department of Natural Resources, Division of Water, 15 p., 11 fig., 33 data tables

Yields of the Unconsolidated Aquifers of Ohio, 2000: Columbus, Ohio Department of Natural Resources Division of Water Resources, 1 map (scale approx. 1:400,000)

Ohio Div. Geological Survey, 2006, Known and probable karst in Ohio: Ohio Dept. Natural Resources, Div. Geological Survey Map EG1 with text

Figure II.B.3.a.01 Elevation contours on the base of the deepest underground source of drinking water (USDW) in Coshocton Co. Modified from Riley, 2012

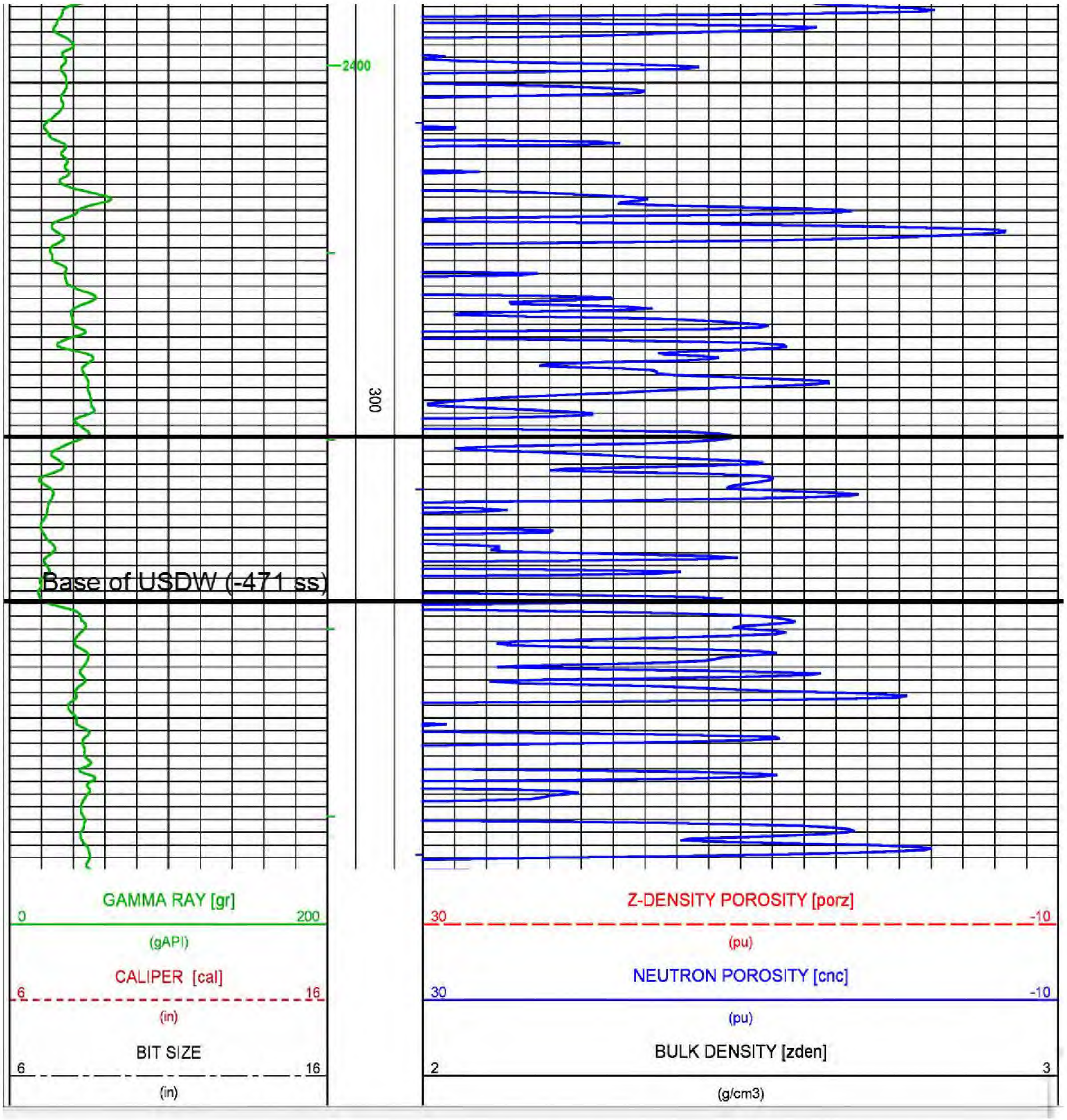


Figure II.B.3.a.02 Wireline log segment showing what is most likely attributed by the Ohio Geological Survey as the base of the USDW based on Riley, 2012 (Cased hole gamma ray-neutron log taken from Buckeye Brine No. 2 Adams - API #34031271780000)

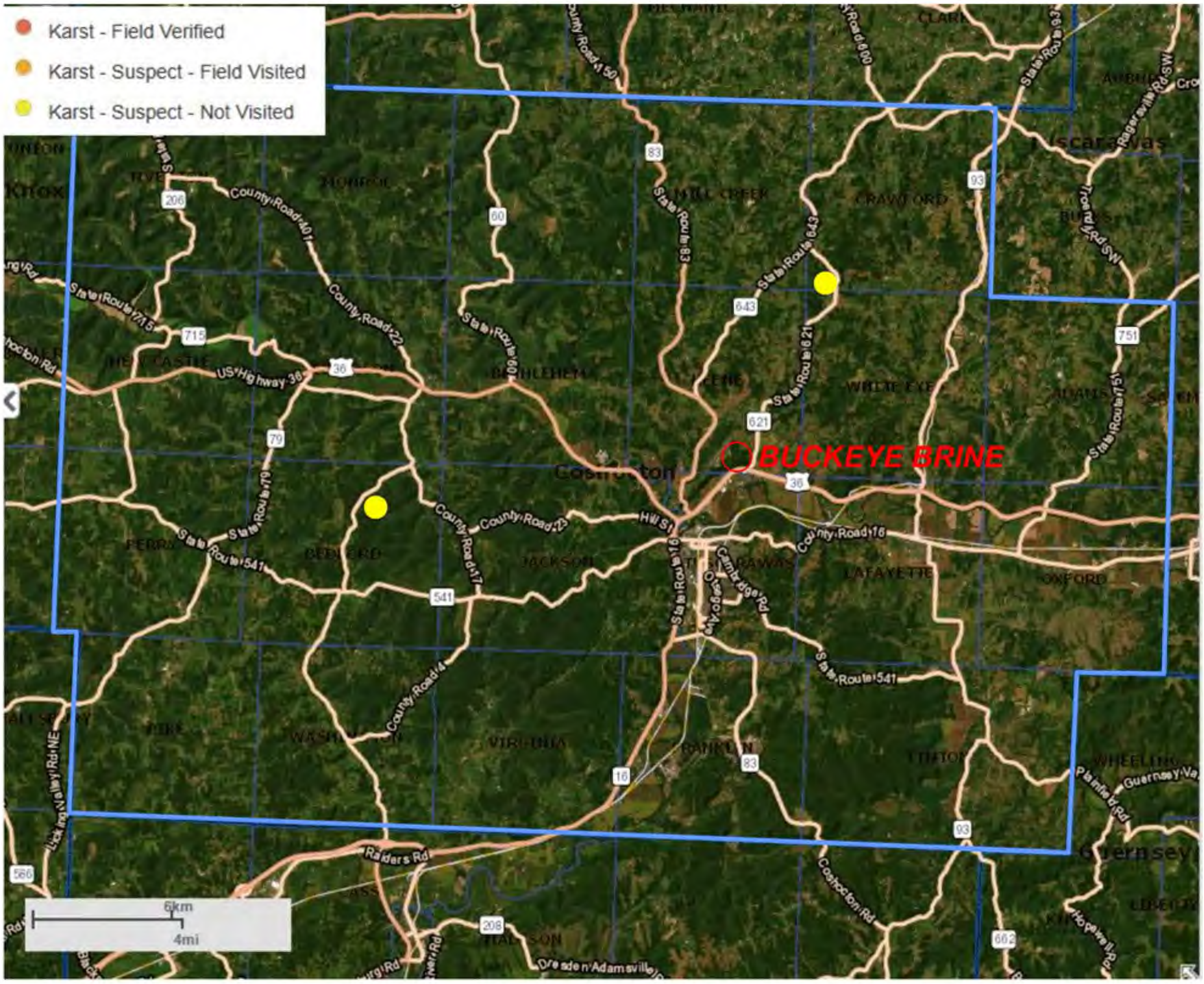
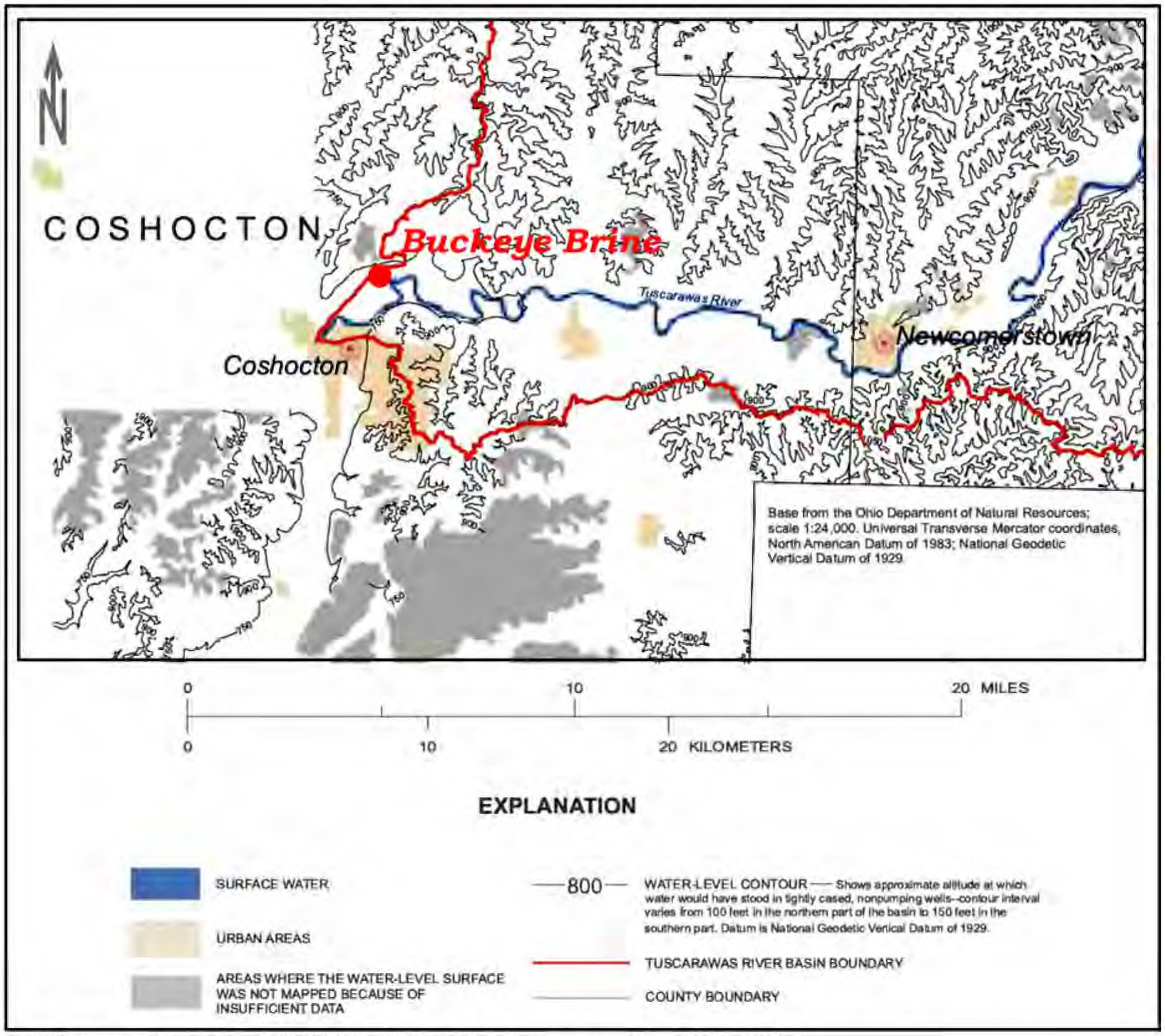


Figure II.B.3.a-03. Local residents may report to the Ohio Geological Survey what they think might be karst features. Two such surface features (yellow) within Coshocton County are identified by the Geological Survey interactive maps as "karst – suspect – not visited/verified."



modified from: Summary of Hydrologic Data for the Tuscarawas River Basin, Ohio

Figure II.B.3.a.04 Map segment showing uppermost subsurface water levels in a portion of the Tuscarawas River Valley

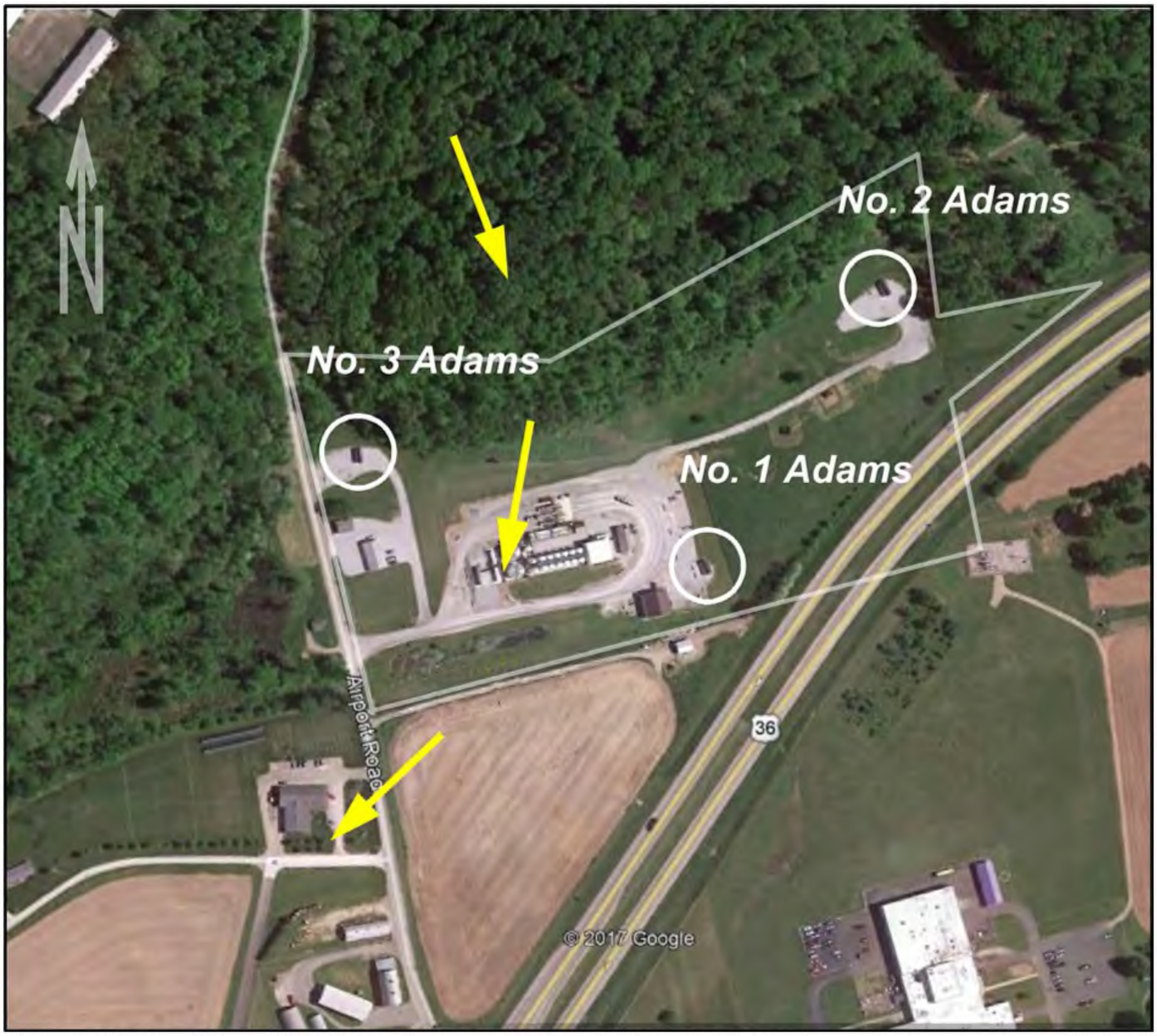


Figure II.B.3.a.05 Direction of groundwater flow across Buckeye Brine property based on surface topography indicators.

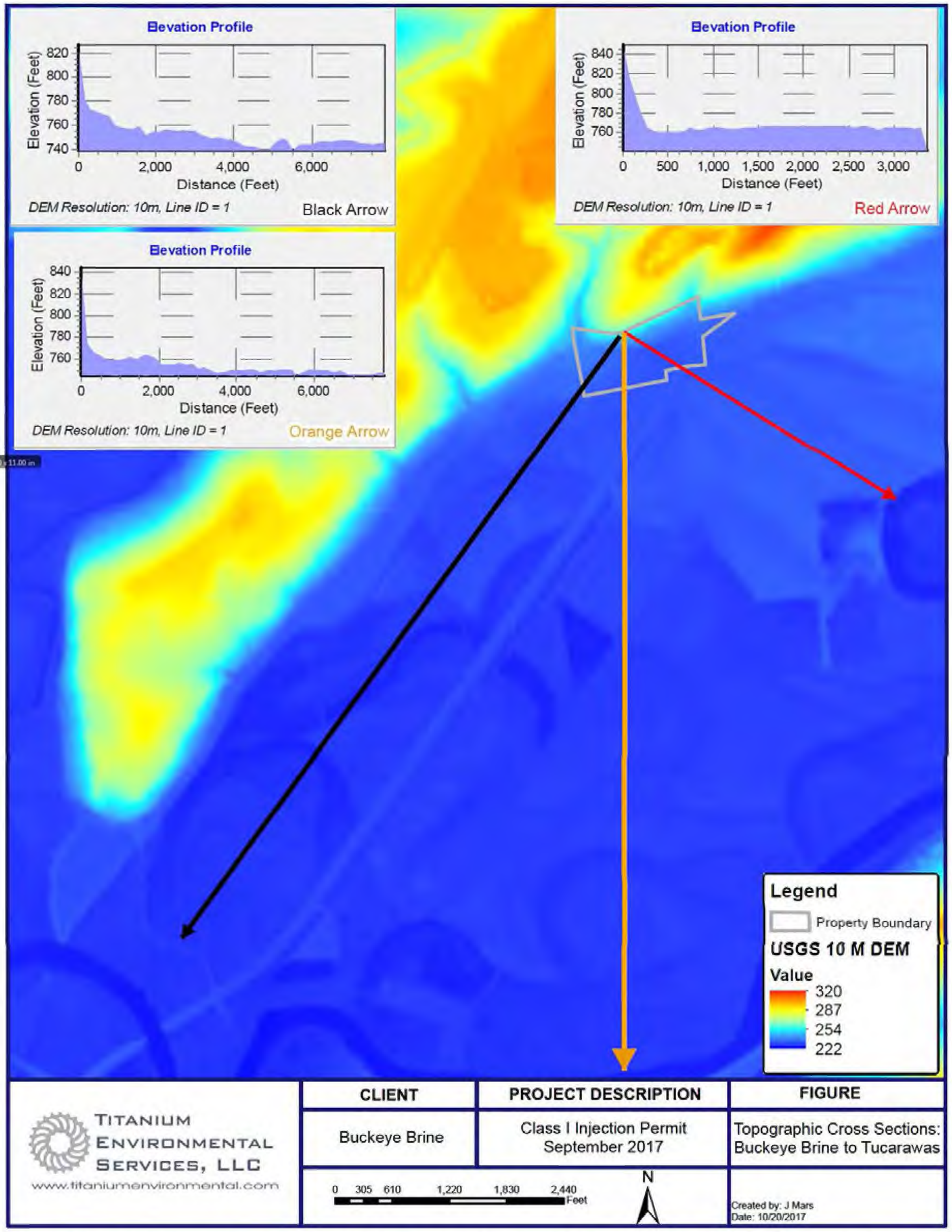


Figure II.B.3.a.06 Ground surface section lines emanating from a common point on the Buckeye Brine property.

II.B.4 LOCAL ECONOMIC GEOLOGY

Industrial Mineral

The industrial minerals that have been exploited in Coshocton Co. include limestone (flux and building), sandstone (building and casting), shale and clay (brick, tile, and ceramics), as well as sand and gravel. A locally available, low-grade iron carbonate has been noted as a historic mineral resource.

Excepting sand and gravel, each of the various industrial minerals within the area of interest are thin and not of the best quality. Consequently, limestone and sandstone are passed over in favor of thicker beds in other parts of the County. Similarly, the local clays and shales are not a primary target of recovery except as might have been convenient accessories to the several coal mining operations.

Coal Resources

Some coal mining has occurred within the AOR, both as surface and subsurface operations. Chiefly, the coal is derived from the 3 ft. thick Middle Kittanning contained within the Allegheny Group that forms the hillsides and hilltops on the north side of the Tuscarawas River valley. The associated Clarion, Lower Kittanning, and Upper Freeport coals of the Allegheny Group are, in some combination, either too thin, erratically developed, or of too poor a quality to warrant attention.

The coal beds in the underlying Pennsylvanian Group include the Sharon, Quakertown, and Lower and Upper Mercer; only the latter two occur at or above drainage. Besides lacking lateral persistence and quality, these units are typically too thin (<1 ft.) to for commercial use.

Nine mines of record are located within the 2 mile designated AOR as shown in the table below. Aside from a single subsurface mine, all others were surface operations. Seven of nine are historic and offer few details as to the nature of their operation or their ultimate disposition. None are active. There are no mine openings or points of mine access withing 300 ft. of the Buckeye Brine facility. Also see Fig. II.B.4.01, (map showing active, inactive, and abandoned coal and industrial mines within 5000 ft. of the Buckeye Brine facility.)

Table 1 - Surface and subsurface coal mines in Area of Review, Keene and Tuscarawas
Townships, Coshocton Co.

Permit ID	Permittee	Mine Type	Coal/Zone	Area (ac.)	Status
C1003	Wills Creek Energy	Underground	Middle Kittanning	41.2 ac.	Disturbed
D-1024	Holmes Limestone	Surface	Middle Kittanning	48.9	Released

Permit ID	Permittee	Mine Type	Coal/Zone	Area (ac.)	Status
652	Historic	Surface (?)	*	10 est.	No record
653	Historic	Surface (?)	*	<5 est.	No record
5971	Historic	Surface (?)	Middle Kittanning	30 est.	No record
5972	Historic	Surface (?)	Middle Kittanning	80 est.	Reclaimed
6001	Historic	Surface (?)	var. Allegheny (?)	35 est.	Unreclaimed
6020	Historic	Surface (?)	var. Allegheny (?)	10 est.	No record
6021	Historic	Surface (?)	var. Allegheny (?)	5 est.	Partially reclaimed

* Ohio Geological Survey records variously indicate subsurface coal mining or gravel pit operations

Oil and Gas Development

The Buckeye facility straddles the Keene-Tuscarawas Township (Twp.) line where the earliest oil and gas development was given by Lamborn (1954) as having taken place in 1921 for Keene Twp., and in 1899 for Tuscarawas Twp. The most common objective was the Berea sandstone at about 800 ft., though a few wells reached the deeper (3200 ft.) Clinton sandstone. Until the mid-1950s and the utilization of hydraulic fracturing, the results were typically unfavorable even though shows of oil and gas were common. From the mid-1950s forward, both the Berea and Clinton have seen slow but steady drilling, to the extent that both zones are now in a late stage of development. Both reservoirs produce from stratigraphic traps where variations in reservoir thickness, porosity, and permeability determine a well's economics.

Although the area of interest is on the very eastern edge of the prospective north-south Rose Run gas trend, production has been successfully derived from the Rose Run sandstone (6200 ft.) since the early 1990s. The trapping mechanism for the Rose Run is secondary-stratigraphic, which is to say paleo-erosional remnants, with younger shale and carbonate rocks providing lateral and top seals. Seismic is required to discern the small, 10-20 acre features in the subsurface, but the reservoirs are good and the success rate has been about two-in-three. At this time the development of the Rose Run is considered to be nearly complete.

There have been few penetrations past the Rose Run sandstone in Coshocton Co., and none have encountered oil and gas. What reservoirs that are found are deemed suitable for disposal purposes.

Reference cited:

Lamborn, R., 1954, Geology of Coshocton County: Ohio Division of Geological Survey, 245 p. Plus Map.

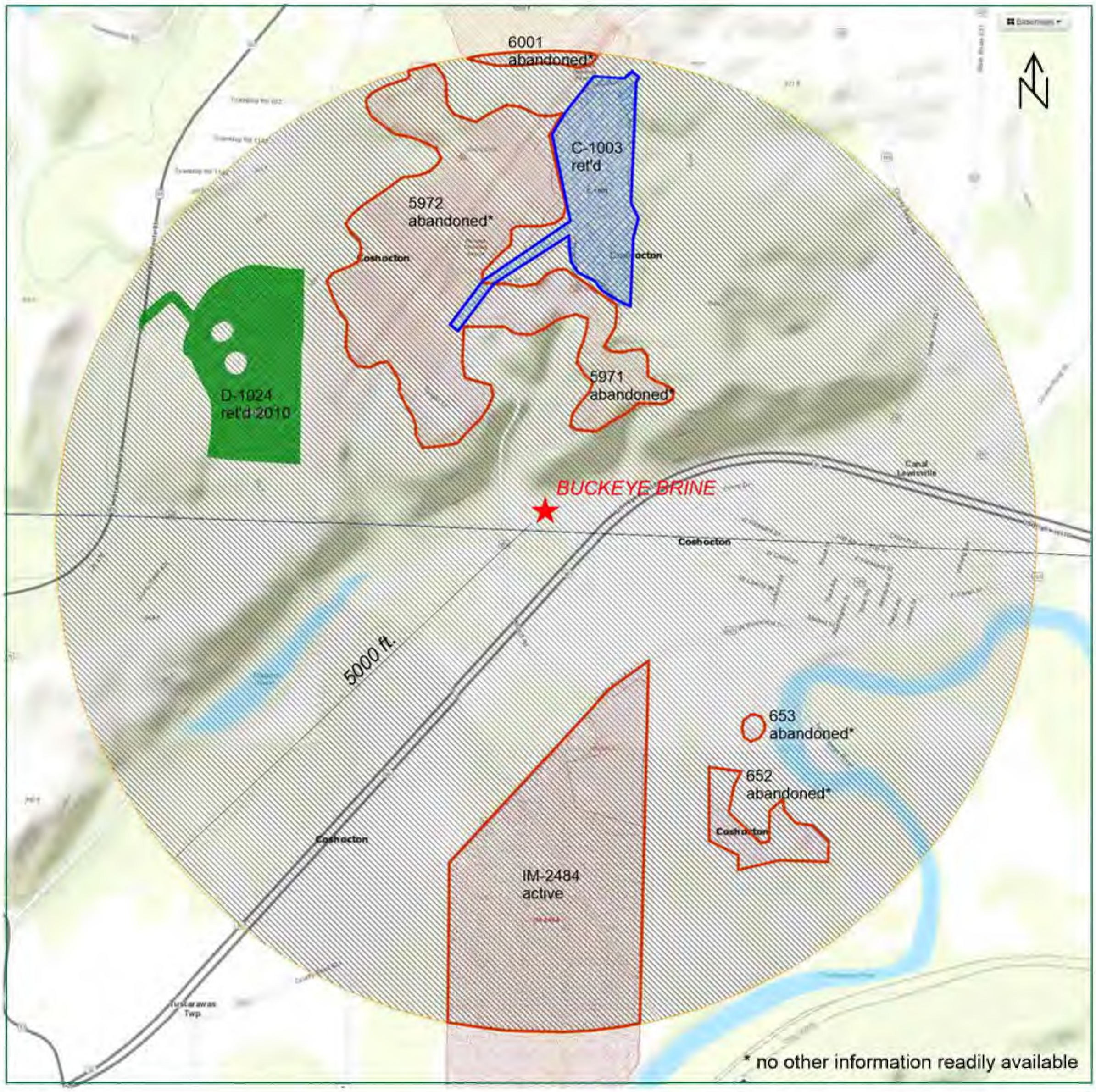


Fig. II.B.4.01. Map showing active, inactive, and abandoned coal and industrial mines within 5000 ft. of the Buckeye Brine facility

II.B.5 LOCAL STRATIGRAPHY

The Buckeye Brine (Buckeye) No. 1 Adams (API #331034271770000), which is located in the center of the Area of Review (AOR) serves as the type log for this discussion (Fig. II.B.5.01). Unless otherwise noted, depths and thicknesses will be referenced to that well.

PRECAMBRIAN

Based on drill cuttings in the Area of Review (AOR), the Precambrian is granitic in composition. Drilling experiences and wireline logs suggest that the upper portion of the Precambrian may be present as a "granite wash," either a highly weathered and/or detrital form of the native rock that is relatively easy to drill.

CAMBRIAN PERIOD

Mt. Simon/Basal Sand

The 80 ft. thick Mt. Simon Sandstone is the lowermost of the Cambrian units. Until very recently the Mt. Simon was considered an omnipresent reservoir across Ohio. However, in eastern Ohio it is of noticeably finer texture and contains a higher percentage of associated dolomite than it does in central and western Ohio. These factors work against its role as a reservoir and the Mt. Simon continues to degrade further to the east. An isolated injection test of the Mt. Simon in the Ohio Geological Survey #1 CO2 (API #34157253340000), 20 miles east in Salem Twp., Tuscarawas Co., similarly determined there was essentially no injection potential (Wickstrom, et al, 2011).

Rome Formation

What is called the Rome Formation (Janssens, 1972) in eastern Ohio is considered as having two identifiable parts, a lower arenaceous dolomite section and an upper pure dolomite section.

The approximately 45 ft. thick basal portion of the unit is upwardly transitional from the underlying Mt. Simon Sandstone. It is an arenaceous dolomite with a fine-textured sand content that decreases upward. Some thin (<4 ft.) framework sandstones may be present. None of this lower section has been found to have enough porosity or permeability to act as a reservoir. The upper 600 ft. of the Rome Formation is chiefly a micro-crystalline dolomite with some portions exhibiting a slightly sucrosic texture. Thin (to 3 ft.) vugular porosity zones occur at random horizons within the uppermost 100 ft. of the unit. These porosity zones are interpreted as a collapsed paleo-karst system. The upper boundary of the Rome Formation is considered an unconformity surface.

Conasauga Formation

Throughout much of the literature the Conasauga Formation has been identified as a shale, though it is in fact an interesting sequence of interbedded dolomite, argillaceous dolomite, and shale across most of eastern Ohio. On resumption of deposition in post-Rome time, thin, erratically developed sandstones were among the first sediments deposited. Close comparison of the Conasauga sands in different wells suggests the sands are overlapping and interfingered, and individual beds may have limited lateral continuity.

Knox Dolomite - Lower Copper Ridge (informal unit)

The 235-ft. thick Lower Copper Ridge in the AOR represents a period of constant carbonate deposition is a warm shallow sea. It is composed of a relatively pure micro- to finely crystalline dolomite with a minor clay content. Locally, portions may be sucrosic, particularly near the top. Density and neutron logs typically generate favorable porosity values. Various tests have suggested a small degree of transmissivity, though not as much as would be inferred from the logs. The Lower Copper Ridge in Coshocton and adjacent counties commonly makes water during drilling, especially from the upper half of the unit, which is considered injection reservoir.

Knox Dolomite - Copper Ridge "B" Zone (informal unit)

The informally named Copper Ridge "B" is a 20-ft. thick section comprised of argillaceous dolostones and gray shales. The base of the "B" zone is commonly laced with shell fragments and minor amounts of quartz sand, suggesting a minor unconformity surface or a shallow still-stand. The "B" zone is not known to yield oil, gas, or water in the AOR.

Knox Dolomite - Copper Ridge (informal unit)

Like the Lower Copper Ridge, the 200-ft. thick (upper) Copper Ridge in the AOR is composed of a relatively pure micro-crystalline to finely crystalline dolomite, but differs in that the top of the unit is arenaceous as it transitions upward into the Rose Run sandstone. None of this upper sandy portion is developed as a framework sandstone. Despite the appearance of porosity on well logs, there is little to no apparent permeability to back it up.

Knox Dolomite - Rose Run (informal unit)

Within the AOR the Rose Run was partially eroded away in post-Knox time so that only about 70 of its full, original 100 ft. thick section is present.. The lower sands that are present represent a marine environment that was transitioning to shallower depths, and form a bridge between the underlying non-porous Copper Ridge carbonates and the porous, coarser grained Rose Run sands that would be present had they not been eroded away. The reservoir properties of these lower sands appear good as depicted on wireline logs, but in practice their combined porosity and permeability fail to offer more than possible supplemental injectivity.

Knox Dolomite - Beekmantown (informal unit)

Within the AOR, the Beekmantown was eroded away from the Knox Group along with the top of the underlying Rose Run. The Beekmantown will not be present in local wells unless it is contained in a Knox erosional remnant with more than enough height to also preserve the uppermost 40-50 ft. of the Rose Run.

ORDOVICIAN PERIOD

Wells Creek Formation

The Wells Creek Formation resides uncomformably on surface of the Knox Group. The formation is comprised three distinct lithologies, a lower dolomitic shale, an intermediate calcareous shale, and an upper limestone. These distinct, readily identified units give rise to considerable confusion as regards the nomenclature for the Wells Creek. In popular (i.e. oilfield) usage where most of the first hand exposure to the rocks occurs, the lower two lithologies may be collectively referred to as Glenwood, and the upper unit denoted as Gull River. Alternately only the lower unit gets the Glenwood notation and the middle unit may be identified as Lower Chazy.

Locally, the Wells Creek Formation has a total thickness of 100-120 ft., the thicker section being characteristic of a regional setting, and the thinner being associated with high-standing Rose Run erosional remnants.

Black River Group

The Black River Group was deposited on a stable, shallow, low-relief platform. It is about 750 ft. thick along the eastern edge of Ohio, thins to about 450 in central Ohio, and more or less maintains that thickness across the remainder of the State. Lithologically, it is predominantly a brown or dark gray-brown, dense, finely- to micro-crystalline limestone. The upper portion of the unit may contain one or more thin (to 4 ft.) bentonite beds, some of which are traceable across much of the State. The lowermost 50 ft. of the unit is argillaceous and contains some thin, black stringers of slightly calcareous shale.

Trenton Limestone

The uppermost carbonate unit in the Ordovician section is the 60 ft. thick Trenton limestone. The product of a slightly deeper environment than the Black River, it can be abundantly fossiliferous toward the top and may contain clay admixtures or thin dark shale.

Point Pleasant Formation

The discussion of the Point Pleasant Formation as presented herein will incorporate the overlying Utica Shale. Continuing the trend of ever deepening water, the Point Pleasant and Utica are generically considered organic black shales. They have a combined thickness of about 240 ft. in the AOR. Their specific lithologies range from dark brown to black argillaceous limestone to calcareous shale. Fossil shell beds may be present, particualrly at the base of the Point Pleasant.

Cincinnatian Group

The entire Cincinnatian-Queenston shale sequence is an approximately 1155 ft. thick Together these units chronicle the prolonged accumulation of clay and silt in an increasingly shallow marine environment. The Cincinnatian is gray shale that grades upward into the shallow-water, silty red Queenston, and culminates with a regional erosion surface.

SILURIAN PERIOD

Clinton Formation

The Ohio Geological Survey denotes the Clinton Formation in eastern Ohio as being comprised of the Medina Sand and the Clinton Sand, the latter of which can be divided into the distinctive White Clinton, and the Red Clinton (Shlucher, 2004).

Medina Sandstone

The Silurian was ushered in with deposition of nearly 200 ft. of shallow water clastics. The first was the Medina which is irregularly developed across Ohio. In the AOR the Medina is only 16 ft. thick. Developed as a clay-laced, quartz cemented silt, it is a barely recognizable marker bed.

Clinton Sandstone

The Ohio Geological Survey denotes the Clinton Formation in eastern Ohio as being comprised of the Medina Sand and the Clinton Sand, the latter of which can be divided into the distinctive White Clinton, and the Red Clinton (Shlucher, 2004).

The Medina is a thin (<20 ft.), silty to fine-grained transgressive, quartz-cemented sandstone deposited on the Queenston erosional surface. Its thickness may be influenced by the paleotopography of the underlying Queenston shale. Within the AOR it is as much as 16 ft. thick. How ver, it is poorly developed, being extremely silty, of low porosity. It serves chiefly as a difficult to identify marker bed.

In the AOR, 60 ft. of especially fissile, dark gray shale separates the Medina from the core sandstone of the Clinton. The Clinton itself is developed as a series of white, interlayered, very fine grained to silty quartz sands with a silica cement. Porosity and permeability is low, rarely exceeding 10% and 10 mD respectively. Individual beds may be as much as 30 ft. thick, but more typically are only 5-20 ft. thick. Nearly everywhere it is drilled, some manner of oil and gas is encountered in marginal to paying quantities. Approximately 60 ft. of blocky gray shale overlies the Clinton sandstones. That shale is capped by an uncomformity durface that is identified by a thin but distinctive rust-red oolitic (carbonaceous) hematite..

Dayton Formation

The Dayton Formation was deposited on the upper erosional surface of the Clinton Formation .as a series of thin transgressive, onlapping carbonate lenses; individual lenses may be 5-40 feet thick, and in the aggregate can be as thick as 60 ft. Precise location determines the thickness of the Dayton Formation and the number of contributing lenses. It is encountered as a medium to fine grained gray dolomite. The Dayton Fm. is popularly referred to as the Packer Shell, an informal moniker derived from century-ago cable tool drillers who used the dolomite bed(s) as a casing seat when drilling to the Clinton sandstone.

Rochester Shale

The 122 ft. thick Rochester shale is the last significant influx of clastics during the Silurian. It is a mix of gray shale and dense, and blocky, red and green marls, the latter occurring primarily in the lower half of the unit.

Lockport Dolomite

The Lockport, commonly referred to as the Newburg where it produces fluid, is a 322 ft. thick transgressive accumulation of carbonates that may range from dolomite to limestone. The lowermost 100-200 ft. of the unit is argillaceous to varying degrees, consistent with a transition from the underlying Roschester Shale.

Salina Group

Sedimentation in eastern Ohio during the late Silurian took place in a restricted, evaporitic basin that left a 505 ft. thick sequence of dolomite and anhydrite that contains a minor amount of thin gray shale. East and north from the AOR, salt is major component of the Salina.. The western limit of those salts, however, is about three miles east from the Buckeye Facility.

DEVONIAN PERIOD

Bass Island Dolomites

The 180 ft. thick Bass Island is the basal member of the Devonian sequence. It has a calcareous dolomite lithology. It is bounded above and below by unconformities.

Helderberg Limestone

The Helderberg Limestone is bounded above and below by unconformity surfaces. Lithologically, it is similar to the underlying Bass Island Dolomite in that it is a dolomitic limestone. Wireline logs portray minor secondary porosity is ascribed to the basal portion of the unit, though no fluid is known to come from the unit within the AOR

Oriskany Sandstone

Oriskany Sandstone is present in the AOR as a well-cemented silty sandstone. The AOR is close to the western edge of the Oriskany's range, and is no more than 10 ft. thick. A short distance from the AOR, the Oriskany sandstone has had minor commercial value as a producer of gas and oil where entrapment is afforded by structure, lateral variations in porosity and permeability, or updip pinchout;.

Onandoga Limestone

As discussed herein, the 156 ft. thick Onondaga Limestne, informally referred to as the Big Lime, is a 141 ft. thick limestone. It is composed of an argillaceous limestone, and is rich in silica, some of which may manifest itself as chert.

Devonian Shales

As used herein, Devonian Shale is used to denote an approximately 1555 ft. thick section of shale between the Berea Sandstone and the Onondaga Limestone. It is comprised principally of the Hamilton Group, which is overlain by the Olentangy Shale, and subsequently by the Ohio Shale.

The Hamilton Group is composed of dark gray to black, fissile, organic shales

Olentangy is composed of a series of gray and black shales, portions of which may be calcareous or include thin beds of limestone. None of the black shales contained in the Olentangy have a high enough total organic carbon (TOC) content to warrant consideration as hydrocarbon reservoir, though they may have generated some hydrocarbon that found its way to other reservoirs above or below.

The Ohio shale as discussed herein includes, from bottom to top, the Huron, Chagrin, and Cleveland members. Except for portions of the Huron member that contains some low TOC black shale, the interval is composed of gray shale that grades to a brown-gray or brown-black near the top.

Bedford Shale and Berea Sandstone

The silty nature of the Bedford Shale points to its transition to the overlying Berea sandstone. Neither is prominent in Coshocton County, each unit being about 20 ft. thick within the AOR. The Berea Sandstone is a thin, shallow-water, blanket type deposit that is composed of a silty, very fine grained, mechanically cemented gray sandstone with modest porosity (to 10%) and permeability. Within the AOR it is about 20 ft. thick and has produced very minor amounts of oil and gas.

MISSISSIPPIAN PERIOD

Sunbury Shale

Referred to by cable tool drillers as the "Coffee shale" for its distinctively rich brown color, the 40 ft. thick Sunbury shale is organic, slightly silty, and breaks easily under the drill. Although it does not produce oil or gas by itself, it is at least one source for the oil and gas trapped in the underlying Berea sandstone.

Cuyahoga Formation

Locally, the approximately 150 ft. thick Cuyahoga Formation is composed entirely of a homogenous gray shale. Because it has no commercial value, and is merely a waypoint to other horizons, it is poorly documented. The lowest USDW in the AOR is attributed to the Black Hand (sandstone, locally conglomeratic) member at the top of the Cuyahoga Formation; at this western edge of its range, it is interpreted as a (shallow subaqueous) bar deposit.

Undifferentiated Mississippian and Pennsylvanian Clastics

The Mississippian and Pennsylvanian section above the Cuyahoga shale is comprised of about 500-800 ft. of alternating layers of shale, siltstone, and sandstone, some shaped by cut-and-fill features. In the aggregate, these rocks are poorly documented, rarely given notation on drilling records or described from cuttings, and are almost never characterized with wireline logs. Within the AOR, the

The Mississippian and Pennsylvanian section above the Cuyahoga shale is comprised of alternating layers of shale, siltstone, and sandstone, andveryr thin beds of limestone that resulted from small but rapid fluctuations in depth of burial. Cut-and-fill features abound. The Pennsylvanian contains multiple thin beds of mineable coal. Most of the good detailing of the Mississippian and Pennsylvanian rocks has been an outgrowth of mapping associated coal beds.

References:

Riley, R. A., 2012, Map EG-6, Elevation contours on the base of the deepest underground sources of drinking water in Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey, 1 map (scale 1:500,000).

Wickstrom, L. H., Riley, R. A., Spane, F. A., McDonald, Jas., Sclucher, E. R., Zody, S. P, Wells, J. G., and Howat, E., 2011, Geologic Assessment of the Ohio Geological Survey No. 1 CO2 Well in Tuscarawas County and Surrounding Vicinity: ODNR, Division of Geological Survey, Columbus, Ohio

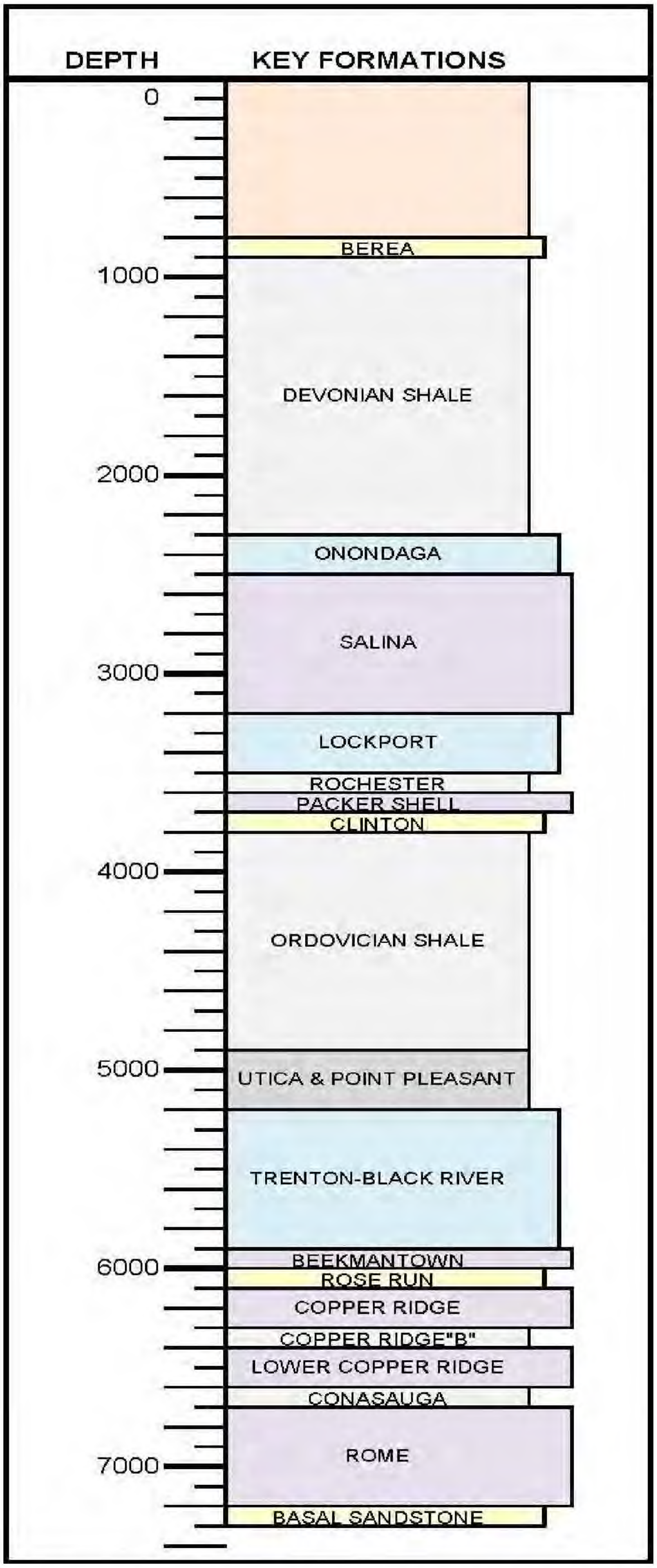


Figure II.B.5.01 - Stratigraphic section showing the key formations and sub-units in the Area of Review, and their approximate drilling depth.

II.B.6 - CHARACTERISTICS OF INJECTION ZONE, CONFINING ZONE, and the LOWERMOST USDW

II.B.6.a - LOWERMOST USDW

The deepest underground source of drinking water (USDW) is defined (<10,000 ppm TDS) by the U.S. EPA. In the Coshocton area and the Area of Review (AOR) this is based on work done by Vogel (1982), which cited the Black Hand sandstone as the base of the USDW. Matchen (2006), however, mapped the Black Hand as an elongated sand body trending north-south and lying about 10 miles west of the (AOR). This throws into question the precise stratigraphic identification of the USDW reservoir. Nonetheless, as later mapped by Riley (2012), the so-called Black Hand is again cited as the deepest USDW and is shown to cover much of eastern Ohio. In the area of review, Riley's base of USDW lies at a depth of about 330 ft. from the surface (Fig. V.B.3.a-01 and Fig. V.B.3.a-02).

The depth to the USDW notwithstanding, culture in the AOR is largely confined to the valleys, where local domestic water is supplied chiefly by shallow domestic wells drilled into the glacial sand and gravel that fills the Tuscarawas River valley. Typically these wells are drilled and cased to a depth of 50-75 ft. and generate excellent yields that average about 35 gallons per minute (gpm). On its map "Yields of the Unconsolidated Aquifers of Ohio," the Ohio Division of Water Resources attributes these valley-drilled wells with potentials in excess of 500 gpm. Static water levels are about 25 ft. below grade. Although a few wells have been drilled to depths of over 100 ft., their yields and static levels are comparable to those of the shallower wells.

On higher ground, away from the valley, water may be obtained from perched sandstone aquifers contained within the Allegheny Group sediments. Yields and static levels are reported as being comparable to those encountered from the sands and gravel in the river valley.

Within all of Coshocton County and the AOR there are no known fractured limestone or karst features that can source fresh water. Keeping in mind that the bulk of the geologic records that might illuminate the nature of the USDW are vested in wells drilled only into the river gravels and sands, but not through, and secondarily in wells drilled into perched clastic aquifers in the hills surrounding the river valleys; data for mapping carbonate reservoirs is practically absent. The best glimpse of the limestone bedrock is afforded by outcrop descriptions by Lamborn (1954); though he does cite the rare limestone outcrop that measures 5 ft., nearly all of the limestone identified in surface outcrops is less than 18 inches thick.
To a lesser degree, Coshocton municipal water is supplied to certain larger public and private facilities such as the Coshocton Co. Regional Airport, the Coshocton Christian Tabernacle church, and retail establishments close by Rt. 36.

Drilling and completion records for domestic wells are maintained by the Ohio Division of Water and are available online. The most recently drilled wells are represented by the most complete and accurate records. Wells that predate permit requirements may or may not be represented by a driller's record. Instances of more than one well using the same well identification number are common All known wells have been attributed with geographic co-ordinates.

References cited:

Matchen, D. L., Kammer, T. W., 2006, Incised valley fill interpretation for Mississippian Black Hand Sandstone, Appalachian Basin: Sedimentary Geology No. 191, Elsevier, 113 p.

Riley, R. A., 2012, Map EG-6, Elevation contours on the base of the deepest underground sources of drinking water in Ohio: Columbus, Ohio Department of natural Resources, Division of Geological Survey, 1 map (scale 1:500,000).

Spahr, P. N., 2000, Yields of the Unconsolidated Aquifers of Ohio: Ohio Dept. Natural Resources Division of Water Resources, open-file digital map

Vogel, D. A., 1982, Salt/fresh water interface, ground-water mapping porject - Final report to U.I.C. Program: Columbus, Ohio Department of Natural Resources, Division of Water, 15 p., 11 fig., 33 data tables

Yields of the Unconsolidated Aquifers of Ohio, 2000: Columbus, Ohio Department of Natural Resources Division of Water Resources, 1 map (scale approx. 1:400,000)

Figure II.B.6.a-01 Elevation contours on the base of the deepest underground source of drinking water (USDW) in Coshocton Co. Modified from Riley, 2012

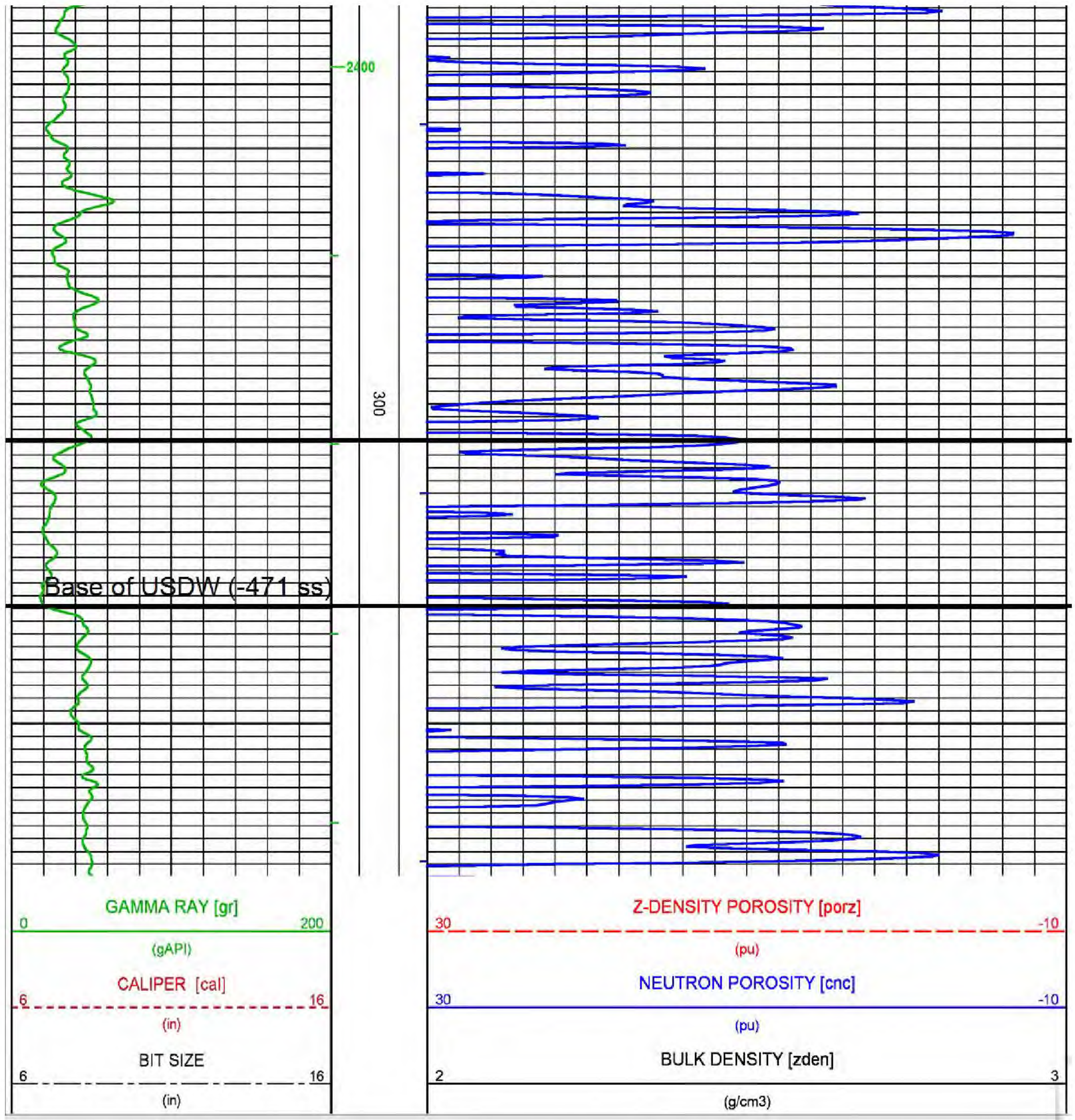


Figure II.B.6.a.02 Wireline log segment showing what is most likely attributed by the Ohio Geological Survey as the base of the USDW based on Riley, 2012 (Cased hole gamma ray-neutron log taken from Buckeye Brine No. 2 Adams - API #34031271780000)

II.B.6.b - CHARACTERISTICS OF THE CONFINING ZONE

The Buckeye Brine No. 4 Adams is to be completed openhole. The casing is programmed to be set to the base of the Rose Run Sandstone at a depth of approximately 6070 ft. The confining zone is considered that portion of the wellbore above the production casing seat. The purpose of the confining layer is to insure protection of shallower zones that are capable of providing potable water. A competent confining zone must be laterally continuous, and free of fractures and faulting that would permit vertical migration of injected fluids. A portion of the confining layer must be sufficiently plastic to accommodate unforeseen stresses without allowing passage of fluids.

The discussion that follows presents the general characteristics of each unit. So as to not distract the dialogue with details of possible lithology changes across the breadth of the State, these comments are generally meant to imply a 25-miles radius beyond the Area of Review (AOR). The thicknesses cited in this section reflect the norm within the AOR. It should be kept in mind that all of the referenced formations thicken slightly to the east, and similarly thin to the west.

Within the Area of Review (AOR) the confining zone is approximately 2270 ft. thick and consists of approximately 105 ft. of the Knox Group (Rose Run), 770 ft. of Ordovician limestone and calcareous shale, and 1395 ft. ft. of Ordovician shale.

The Rose Run Sandstone (Fig. II.B.6.b.01)*, where fully represented within the AOR, is about 100 ft. thick. However, locally it is truncated against a regional unconformity surface so that only two-thirds of that thickness is commonly present. Small (to 20 acres), isolated erosional remnants that are encased laterally and overhead by the impermeable Wells Creek Formation, may be host to accumulations of oil and gas. Porosity within these remnants was likely enhanced by subaerial exposure to 10-15 percent. Where the wellbore does not penetrate an erosional remnant, the Rose Run lacks a lateral seal and does not contain oil & gas. That portion of the Rose Run that resides below the unconformity was denied the enhancement to porosity; there it is a relatively poor conductor of fluids, having porosity that rarely exceeds 10 percent. Openhole injection testing performed on the adjacent Buckeye Brine No. 1 Adams indicated that no fluid was entering the Rose Run Sandstone.

The Wells Creek Formation is composed of dense, extremely non-porous, non-permeable rock with excellent lateral continuity. The Wells Creek Formation ranges from a distinctive pale green, argillaceous dolomite with included shale to a dense micritic limestone. The Wells Creek Formation provides the seal against upward oil and gas from the underlying Rose Run

The combined Black River Group and Trenton Limestone sections are 650. ft thick. The Black River Group (Fig. II.B.6.b.02)* is a massive, uniformly dense, non-porous, non-permeable, micro- to very finely crystalline limestone, not unlike the underlying Wells Creek Formation. The upper portion of the unit may contain one or more thin (to 4 ft.) bentonite beds, some of which are traceable across much of the State. The lowermost 50 ft. of the unit is argillaceous and contains some thin, black stringers of slightly calcareous shale. Lateral continuity is excellent. The approximately 55-ft. thick Trenton limestone is composed of a very fine to coarsely crystalline limestone, and is abundantly fossiliferous at the top, becoming less so toward the bottom. Portions of the unit may be argillaceous or contain very thin stringers of black shale. Lateral continuity is good, any variations being vested primarily in very minor thickness changes.

The Point Pleasant Formation (Fig. II.B.6.b.03)* is generically considered organic black shale. Within the AOR it has a combined thickness of about 240 ft. Its specific lithologies range from argillaceous limestone to calcareous and organic shale.. Fossil shell beds may be present, particularly near the base of the Point Pleasant. The Point Pleasant is considered impermeable.

The Cincinnatian Group is an approximately 755 ft. thick section of gray shale. Because few wells are drilled deep enough to reach the Cincinnatian and because it has no known commercial value, little attention has been paid to the unit. It remains poorly understood and poorly described. Where the Cincinnatian has been reached by the drill, it yields no shows of any kind and is thus regarded as impermeable and barren of fluids. Lateral continuity is excellent.

The Queenston is an approximately 400 ft. thick red, silty shale. The boundary between the Queenston and the underlying Cincinnatian is transitional.. Having no commercial value, the Queenston is rarely given more than a cursory look, but based on drilling observations, it is considered to be an impermeable, non-reservoir rock.

** The illustrated sections are derived from the openhole wireline images for the offsetting Buckeye Brine No. 3 Adams due to its more comprehensive log suite.*

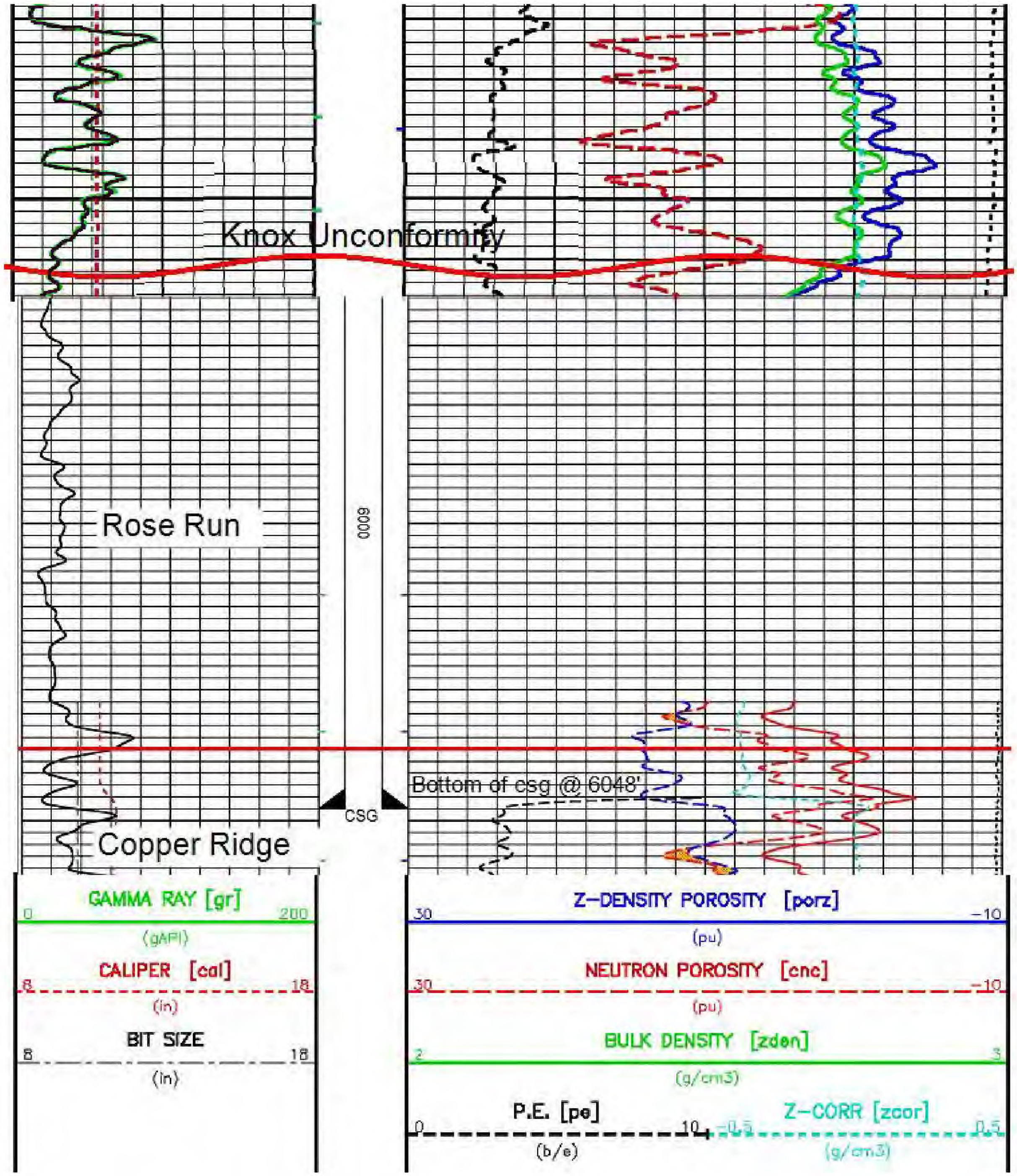


Figure II.B.6.b.01 - Log segment illustrating the thickness and position of the Rose Run sandstone in the Buckeye Brine No. 3 Adams, API #34031272410000. Because the Rose Run is always proximal to the casing point for the production casing, full wireline log representation is usually not possible

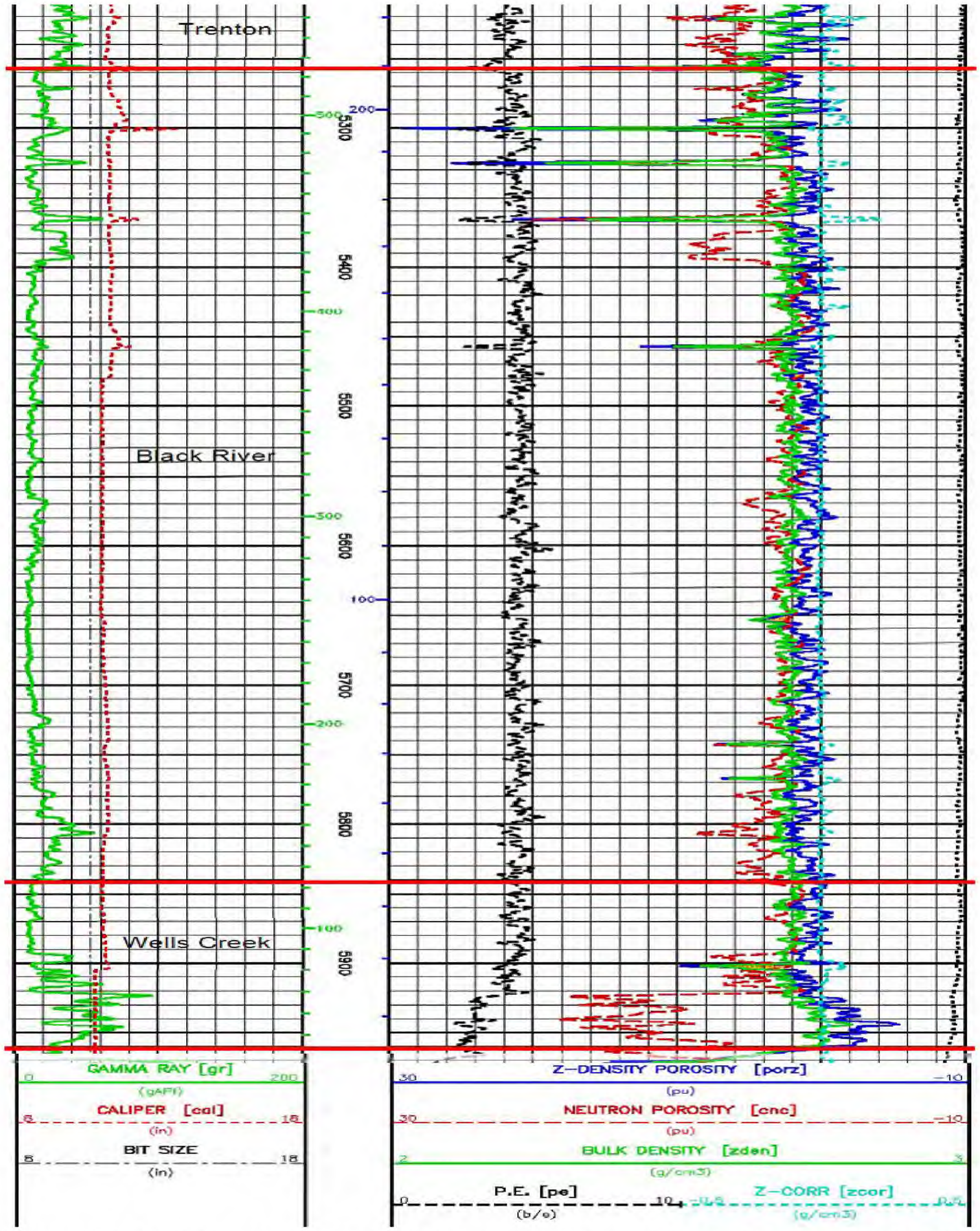


Figure II.B.6.b.02 - Log segment illustrating the uniform density of the Black River limestone, the included bentonite beds, and the slightly more irregular nature of the Trenton limestone (Buckeye Brine No. 3 Adams, API #34031272410000)

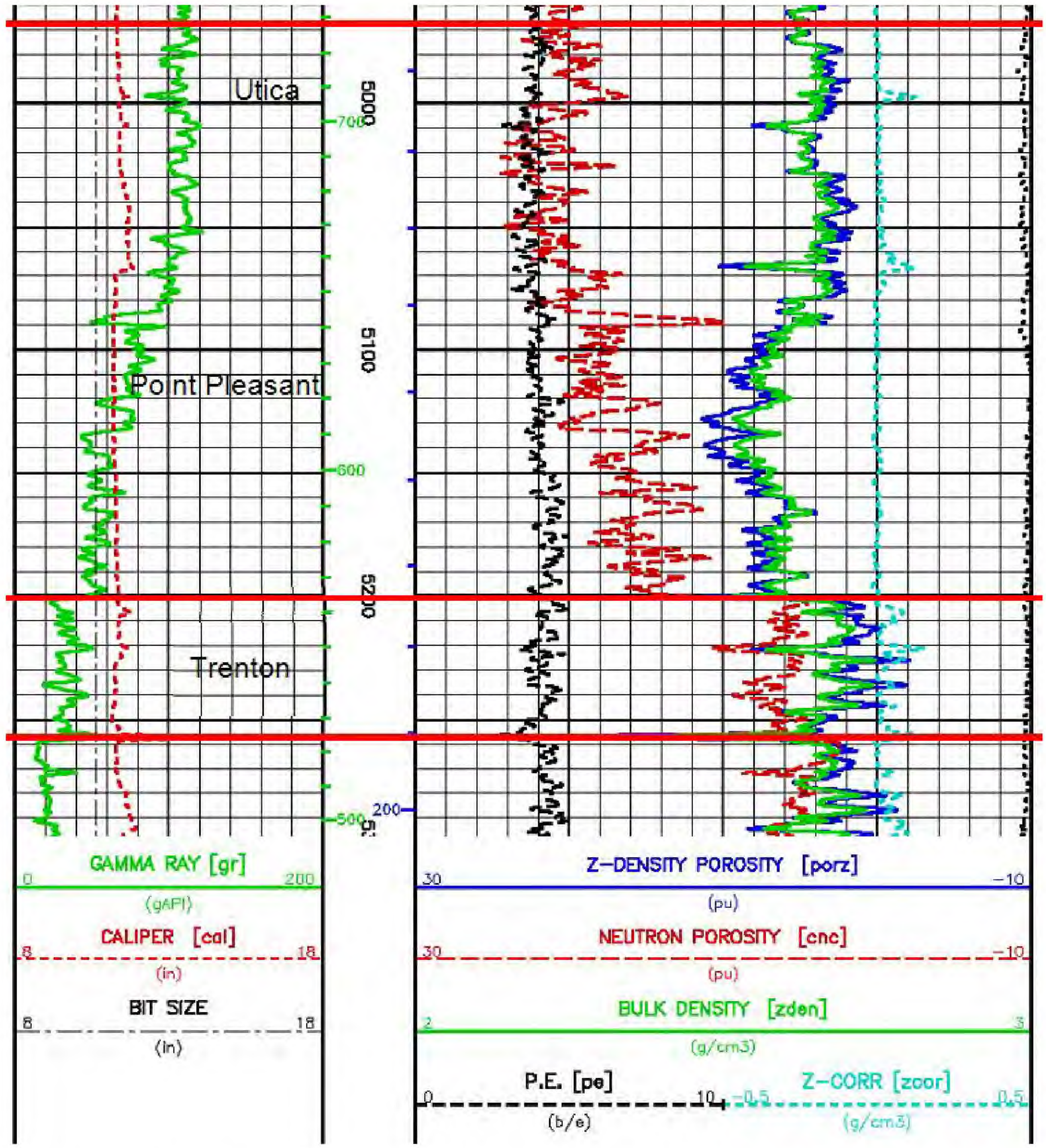


Figure II.B.6.b.03 - Log segment showing the low density/high total organic carbon character of the Point Pleasant and more conventional appearing Utica (Buckeye Brine No. 3 Adams, API #34031272410000)

II.B.6.c - INJECTION INTERVAL

The Buckeye Brine No. 4 Adams is to be completed openhole. The casing is programmed to be set to the base of the Rose Run Sandstone at a depth of approximately 6070 ft. The confining zone is considered that portion of the wellbore above the production casing seat. The purpose of the confining layer is to insure protection of shallower zones that are capable of providing potable water. A competent confining zone must be laterally continuous, and free of fractures and faulting that would permit vertical migration of injected fluids. A portion of the confining layer must be sufficiently plastic to accommodate unforeseen stresses without allowing passage of fluids.

The total depth in the No. 4 Adams is projected to be about 7000 ft., this penetrating approximately 465 ft. of the Rome Formation, this being about 185 ft. above the Mt. Simon Sandstone. Additional injection interval is vested in the Conasauga Formation and the Knox Group (Lower Copper Ridge, Copper Ridge "B", and Copper Ridge). The thickness of the entire injection interval from the base of the casing liner to total depth is estimated to be 930 ft.

The discussion that follows presents the general characteristics of each unit, from top to bottom.

The greater portion of the Copper Ridge is a micro- to very-finely crystalline dolomite that gives little or no indication of porosity on wireline logs.

The Copper Ridge "B" is distinctive on logs and in samples for its high gamma-ray signature that stems from its shale content and included clay material. Within the AOR, the ability of the Copper Ridge "B" to offer stand-alone reservoir opportunities is slight. The clay content can generate low density and high neutron signatures that mimic porosity; but it must be kept in mind that such instances are a falsely optimistic view of the unit (Fig. II.B.6.c.01).

Encountered as a massive, clean dolomite, the Lower Copper Ridge is easily recognized in Coshocton and adjacent Counties. The uppermost portion of the Lower Copper Ridge is commonly sucrosic and well logs may indicate some manner of porosity. During drilling, the lower half of the Lower Copper Ridge commonly gives up at least some measure of fluid, validating observations of texture in the cuttings and porosity values that are generated by the well logs.

The Conasauga Formation is a sequence of interbedded dolomite, argillaceous dolomite, and shale across most of eastern Ohio. The upper part of the Conasauga is a dense, argillaceous dolomite that is not considered to have reservoir potential. One or more thin (to 5 ft.) sandstones may be present in the lowermost 30-40 ft. of the unit; other portions of the unit are arenaceous. Temperature logs from adjacent wells have shown cooling across from these zones, which have also been tested to be capable of receiving injected fluid. There are not enough wide-ranging penetrations and testing to determine the extent of reservoir conditions in the basal Conasauga (Fig. II.B.6.c.02).

Considered as a whole, the Rome Formation is transitional from the underlying Mt. Simon sandstone such that the lowermost 90 ft. has an upwardly decreasing sand content. The sand content is only sufficient enough be identified on wireline logs, but is never so much as to constitute a porous framework sandstone. None of the lower sandy portion of the Rome Formation in the No. 4 Adams will be cut by the drill. The upper portion of the Rome Formation is commonly massive, but may be sucrosic in part; the sucrosic parts may have poor to excellent porosity, but this is invariably subtle, and not easily or accurately quantified with wireline logs. The best porosity is vugular and is developed within the uppermost 100 ft. of the unit. It is attributed to karst development associated with an end-of-Rome paleo-erosional surface (Fig. II.B.6.c.03).

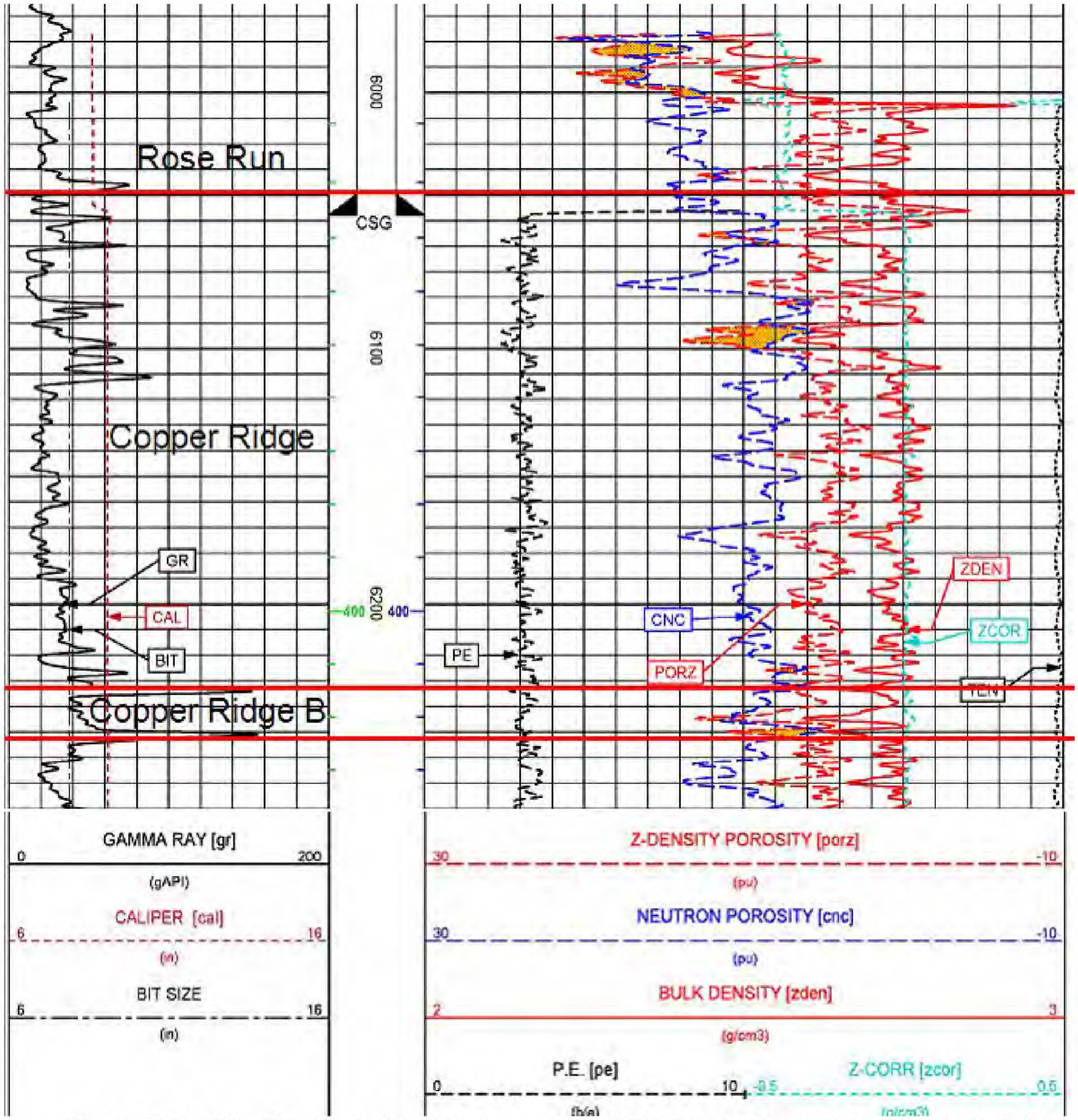


Fig. II.B.6.c.01. Openhole wireline log segment illustrating the general characteristics of the Copper Ridge (Buckeye Brine No. 2 Adams, API #34031271780000)

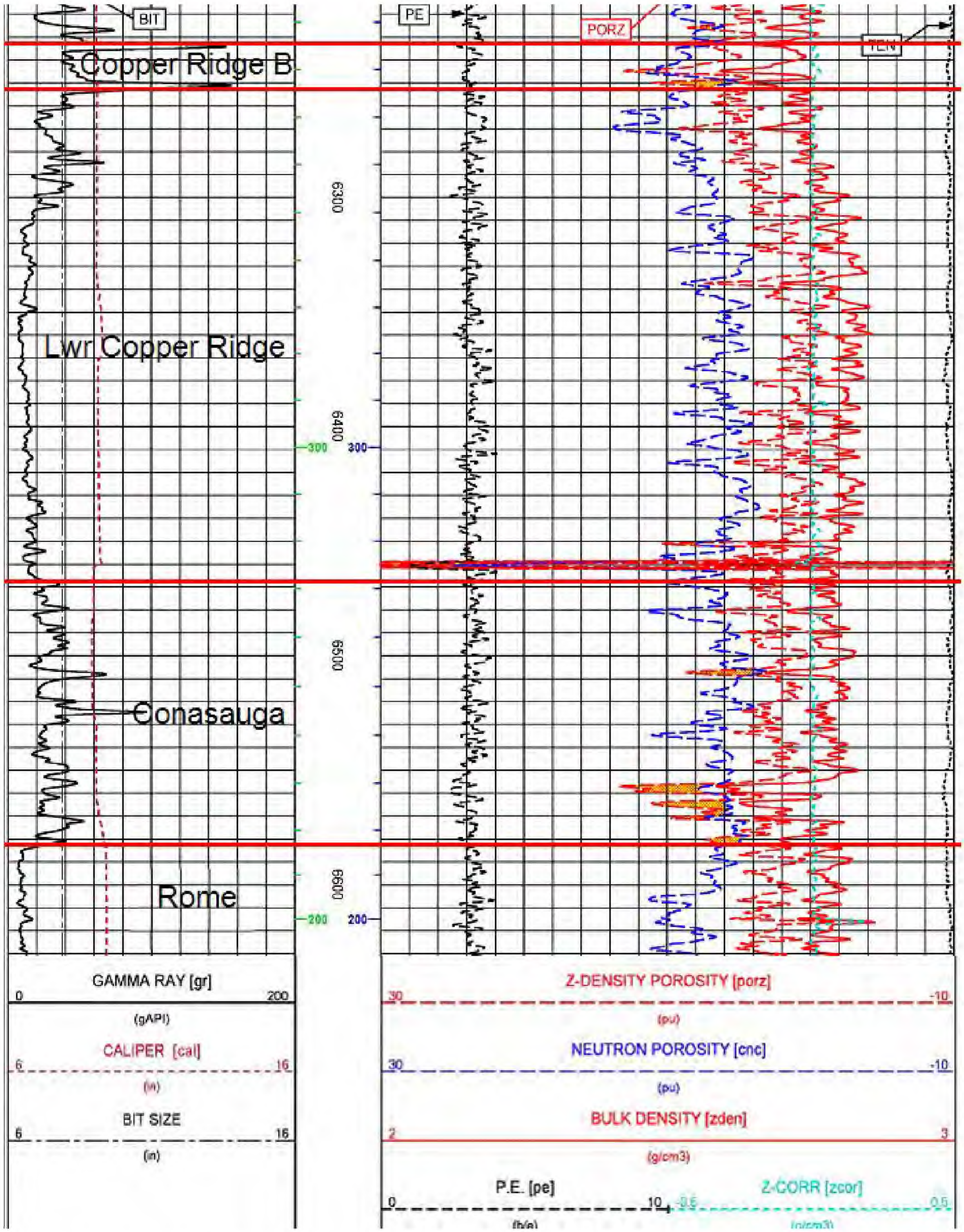


Fig. II.B.6.c.02. Openhole wireline log segment illustrating the general characteristics of the Copper Ridge "B", Lower Copper Ridge, and the Conasauga Formation (Buckeye Brine No. 2 Adams, API #34031271780000)

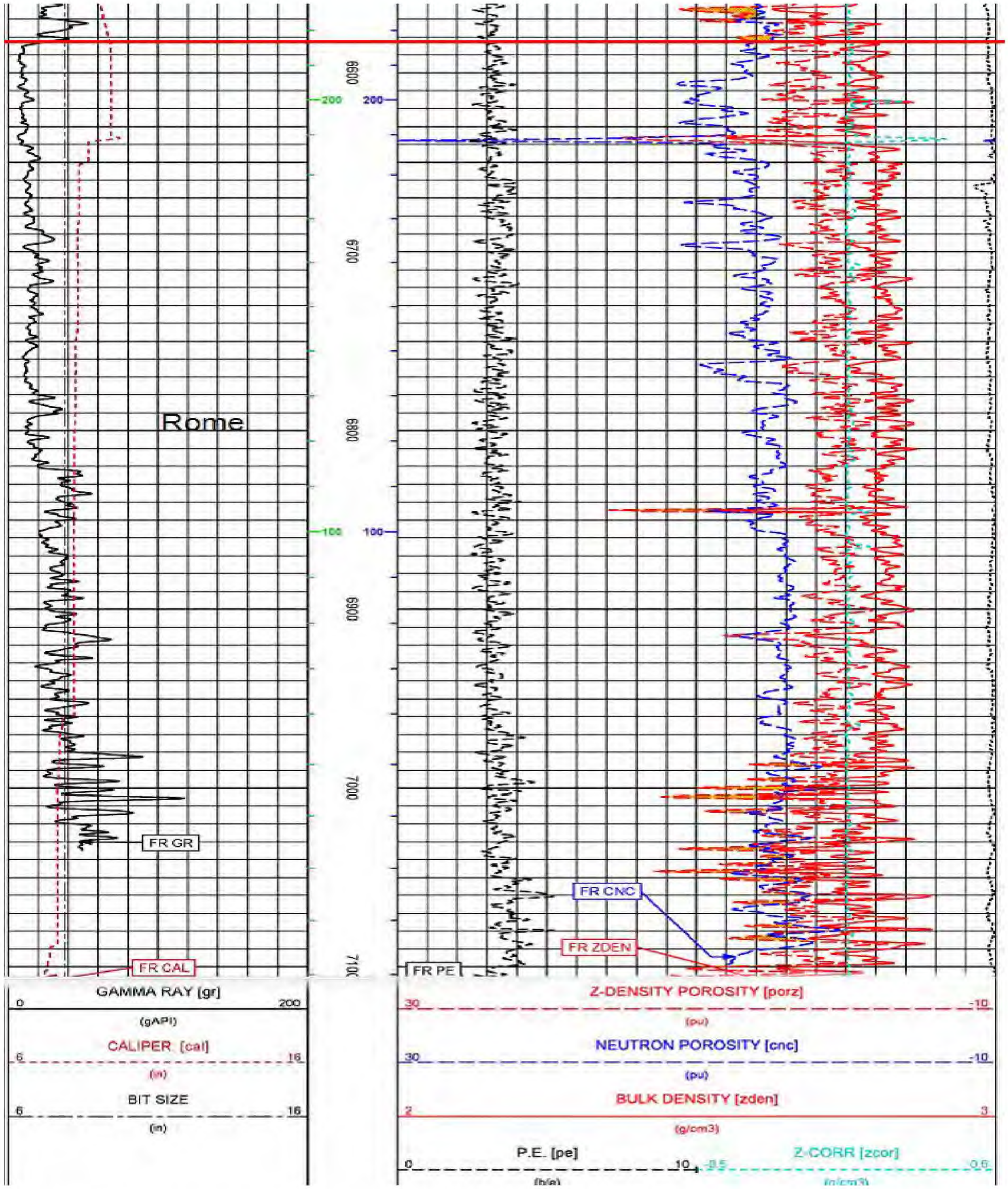


Fig.II.B.6.c.03. Openhole wireline log segment illustrating the general characteristics of the Rome Formation (Buckeye Brine No.1 Adams, API #34031271770000)

II.B.6.d - LOWER CONFINING STRATA

The No. 4 Adams is projected to be drilled to a total depth of 7000 ft. It is estimated that the 465 ft. of the 650 ft. thick Rome Formation will have been penetrated. On that basis the upper portion of the Rome becomes the lowest unit in the injection interval. (Fig. II.B.6.d.01)

The uppermost 150 ft. of the Rome Formation is a massive, micro- to finely crystalline dolomite that is sucrosic in part. Poor to excellent vugular porosity, interpreted as the remnants of a collapsed karst system, may occur at various horizons in this upper portion. The middle portion of the Rome Formation has a similar lithology, but is void of vugs or other indications of porosity.

The basal portion of the Rome Formation is commonly arenaceous to the extent that included quartz and clay may read as porosity on wireline logs when measured against the denser middle and upper dolomitic sections, but none of this has been found to translate into actual porosity. Repeated injection testing of the Buckeye Brine No 1, 2, and 3 Adams wells does not show fluid movement below the uppermost 150 ft. of the Rome Formation.

The Mt. Simon Sandstone in eastern Ohio commonly generates at least moderate porosity values (to 12%) on wireline logs, but the unit generally does not exhibit encouraging permeability. However, those values are not known to have translated to viable injection zones in Coshocton County and points east in Ohio.

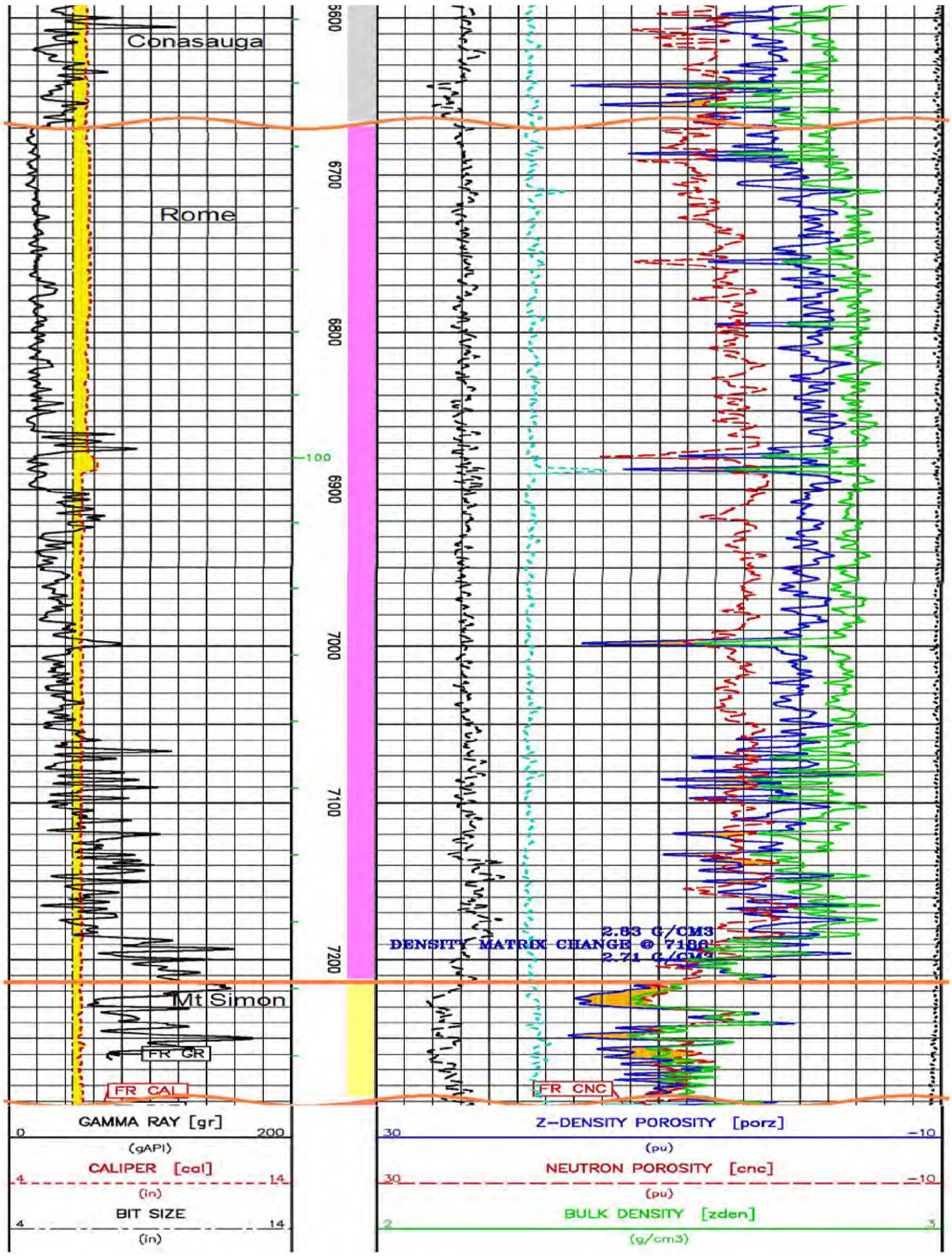


Figure II.B.6.d.01. Openhole wireline log section showing the salient lithologic features of the Rome dolomite and Mt. Simon sandstone (Buckeye Brine No.1 Adams, API #34031271770000)

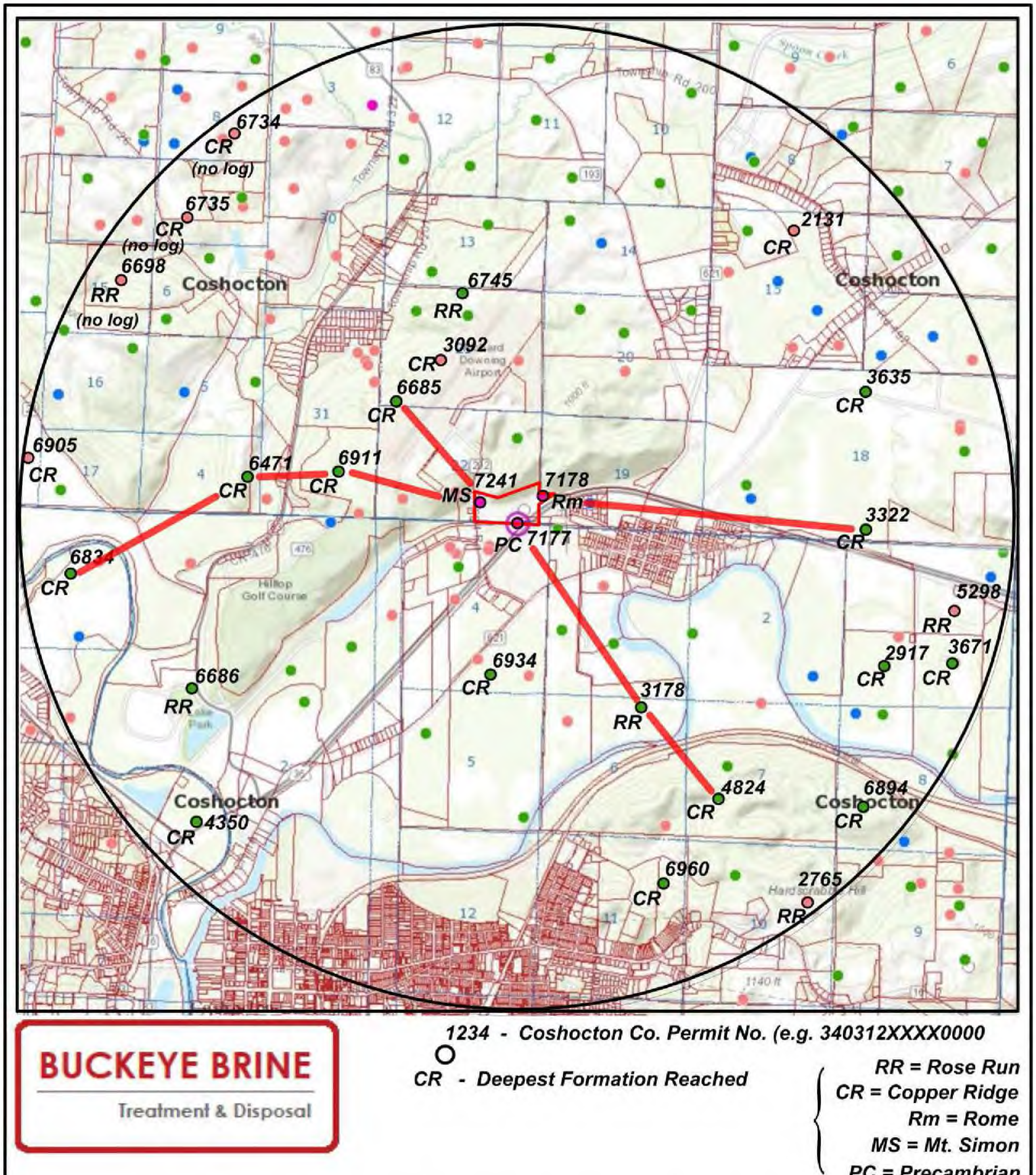
II.B.7 LOCAL STRUCTURAL CROSS-SECTIONS

Using wireline log data from wells within the Area of Review that were drilled into the injection interval, North-South and West-East cross sections were constructed for the purpose of comparison to shallow (<4500 ft.) mapping and reconnaissance seismic that was acquired by Buckeye Brine.

Two versions of each section are presented. The structural section uses a sea level datum. The stratigraphic section uses a top-of-Trenton datum.

The structure sections show the expected southeastward dip, though the north-south line shows this more plainly. Both lines show the moderate undulation that is common at the top of the Knox Group (Rose Run), as well as the high-standing Rose Run erosional remnants that are common targets for oil and gas development. Of particular interest is the apparent structural difference between the No. 3 Adams and the No. 1 Adams.

The west-east stratigraphic section shows some mild eastward thickening of the individual units, as would be expected.



ARTIFICIAL PENETRATIONS INTO THE INJECTION INTERVAL AND LINES OF SECTION INSIDE BUCKEYE BRINE 2-MILE AREA OF REVIEW

Figure II.B.7.01 - Location map highlighting the Buckeye Brine facility inside the 2-mile radius area of review, the artificial penetrations into the injection, and lines of structural and stratigraphic section

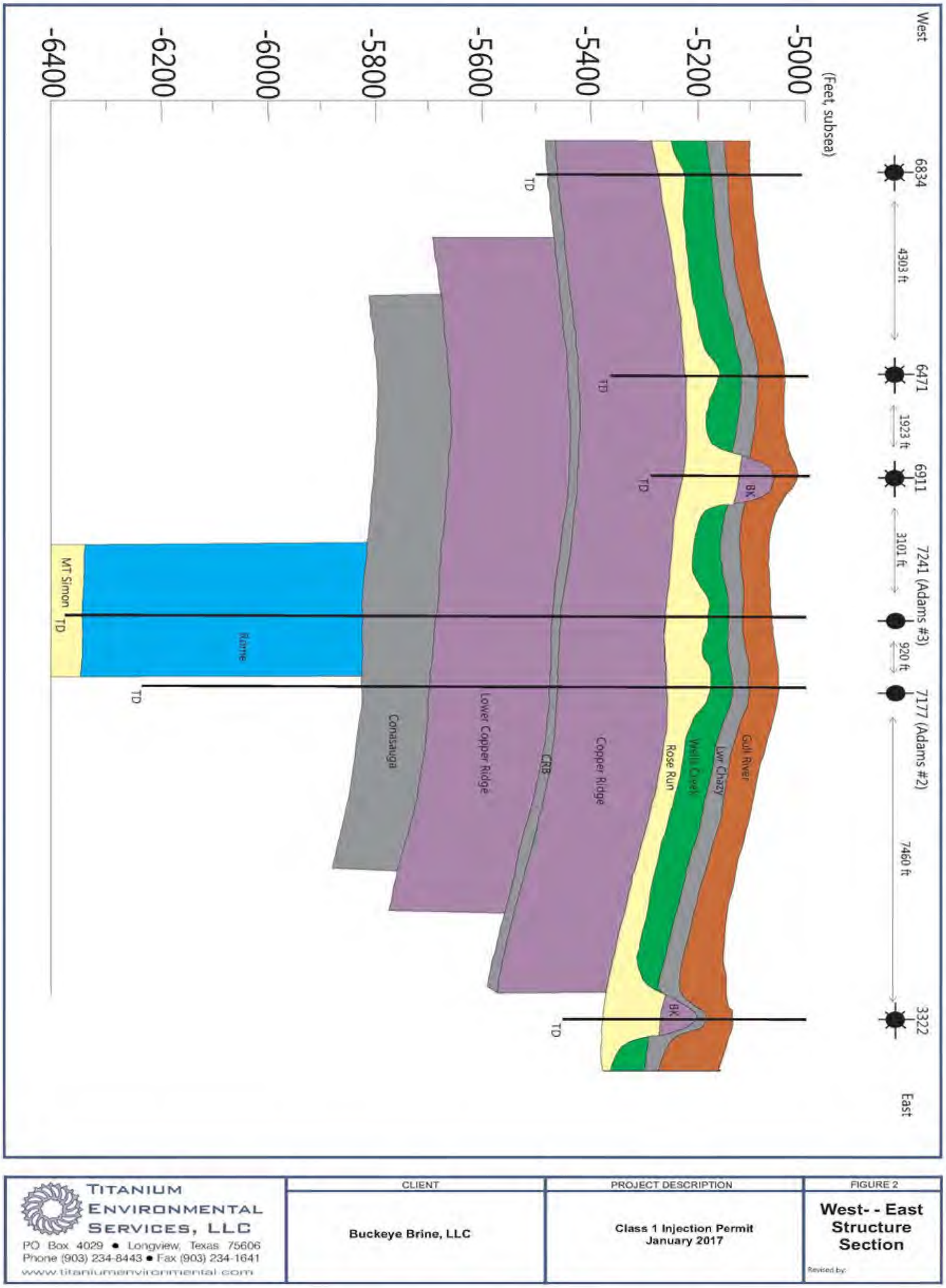


Figure II.B.7.02 - West-East structural section traversing the area of review and passing through the Buckeye Brine facility

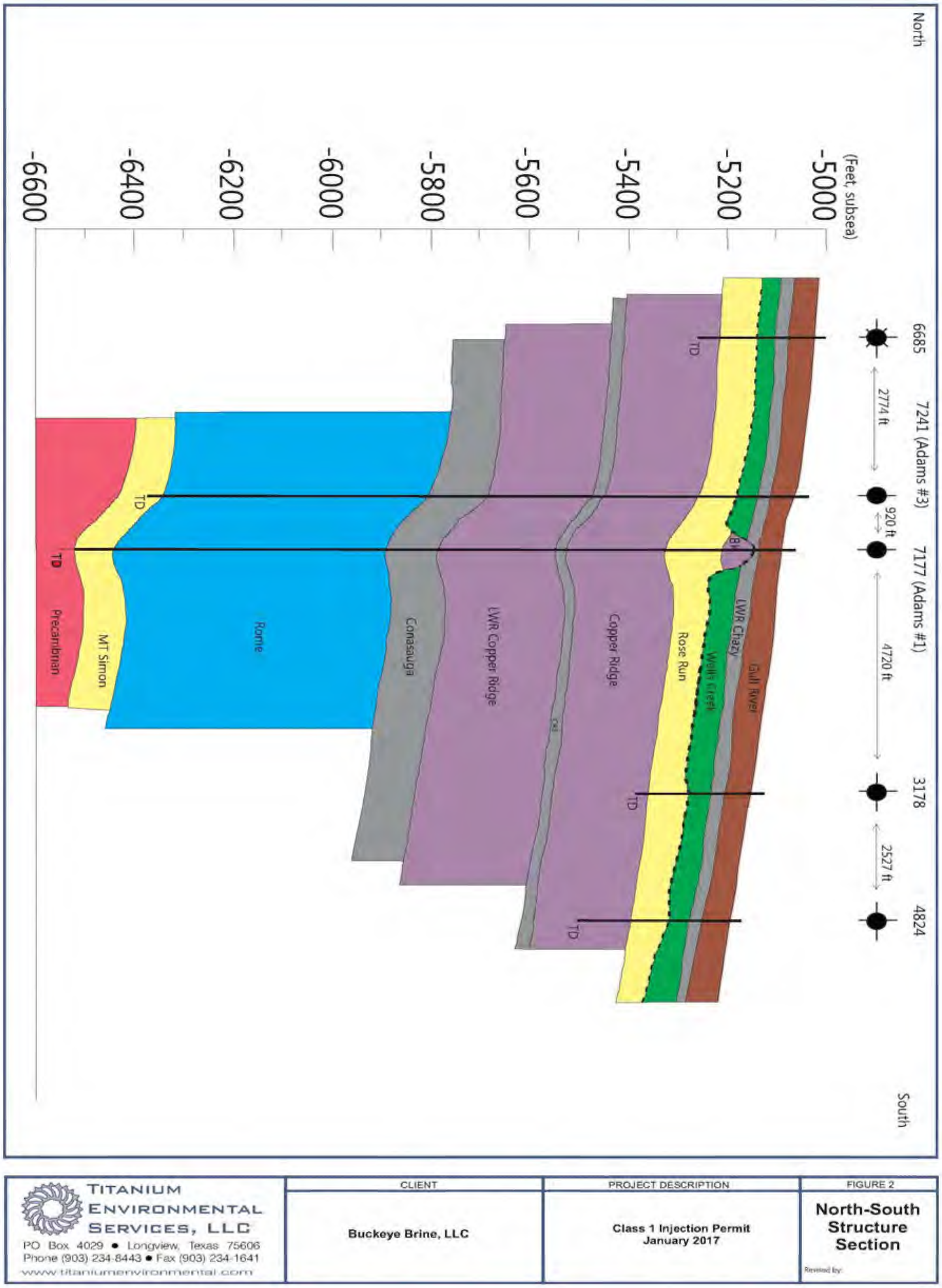
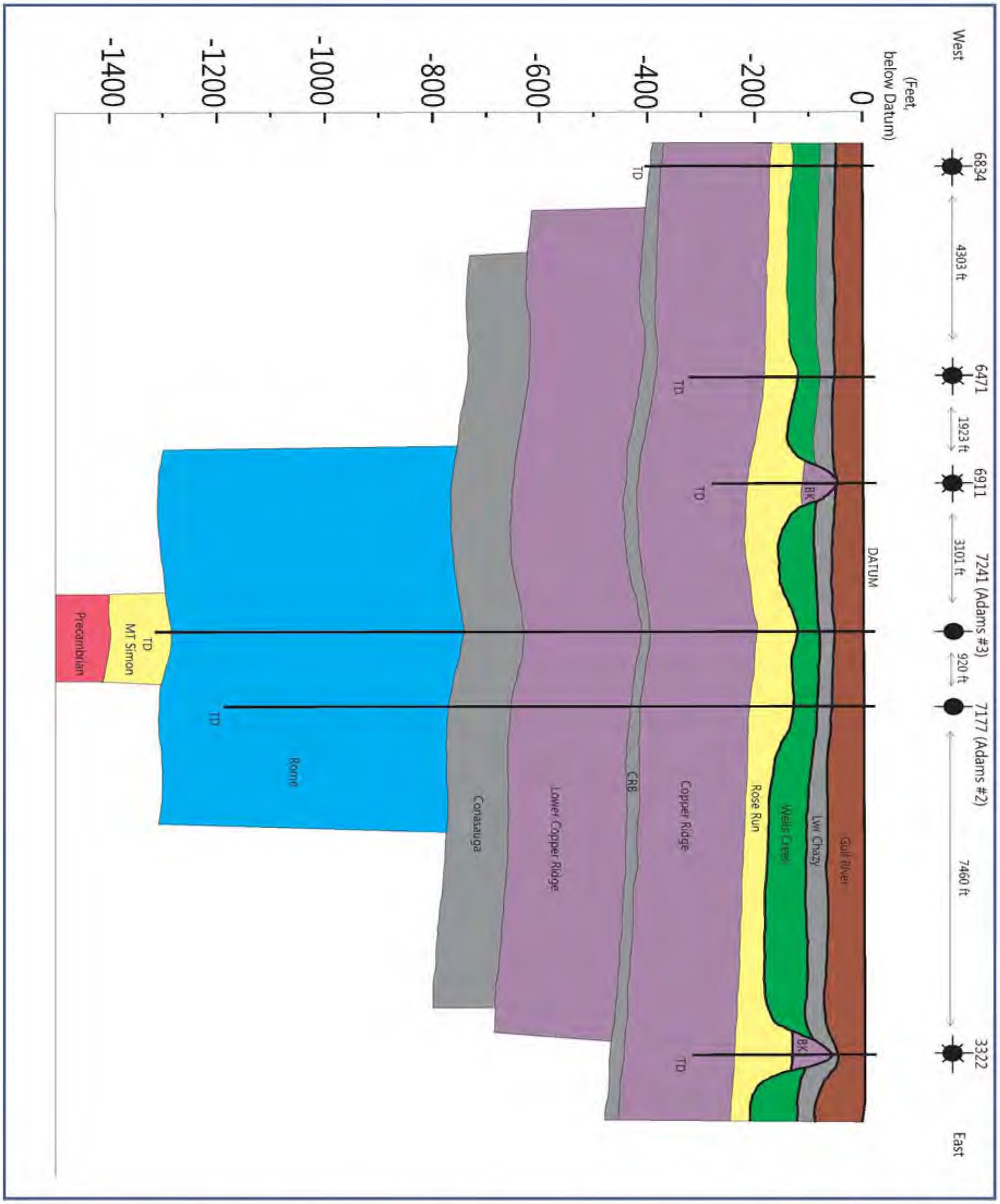


Figure II.B.7.03 - North-South structural section traversing the area of review and passing through the Buckeye Brine facility



TITANIUM ENVIRONMENTAL SERVICES, LLC PO Box 4029 • Longview, Texas 75606 Phone (903) 234-8443 • Fax (903) 234-1641 www.titaniumenvironmental.com	CLIENT	PROJECT DESCRIPTION	FIGURE 4
	Buckeye Brine, LLC	Class 1 Injection Permit January 2017	West-East Stratigraphic Section Revised by:

Figure II.B.7.04 - West-East stratigraphic section traversing the area of review and passing through the Buckeye Brine facility

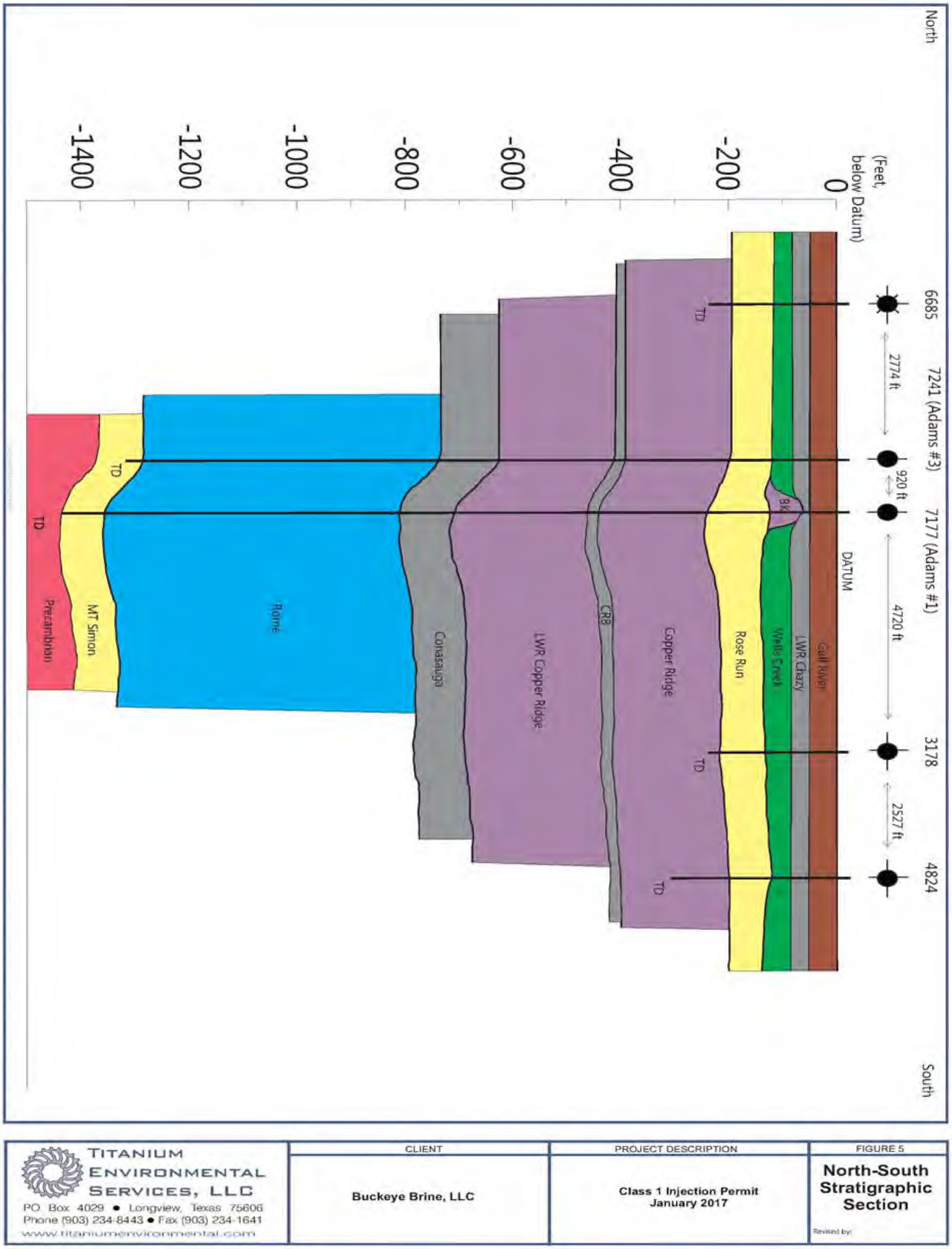


Figure II.B.7.05 - North-South stratigraphic section traversing the area of review and passing through the Buckeye Brine facility

Attachment C

II. Seismic Discussion

II.B.8 LOCAL STRUCTURAL GEOLOGY

A prominent surface lineament that passes close by Coshocton was originally referred to as the Coshocton Fracture Zone (Fig. II.B.8.01). Subsequent references have referred to it as the Coshocton Fault Zone. The control for the lineament was originally built from USGS digital elevation model files (Mason, 1999) and is visible on the Ohio Geological Survey's shaded elevation map. Attributed to surface fractures, the fault zone is speculated to be associated with deep-seated fracture systems. It remains poorly understood and is omitted from most maps that portray basement-influenced structure.

In reporting on the extensively researched Ohio Geological Survey No. 1 CO2 stratigraphic test (API# 3415725334), 20 miles east of the Buckeye facility, it was reported that no regionally extensive, deep-seated faults were identified within 25 miles of the test site (Wickstrom, et al, 2011).

A series of structure maps was constructed from the available well control. The structure maps included the Berea Sandstone (Fig. II.B.8.02), Onondaga Limestone (Big Lime)(Fig. II.B.8.03), and Dayton Formation (Packer Shell) (Fig. II.B.8.04) horizons.

Although the Area of Review (AOR) employs a two-mile radius, mapping was extended three miles east from the Buckeye Brine facility in order to determine the location of the Cambridge Arch.

The Berea Sandstone structure clearly shows the rolled and uplifted anticline on the Berea Sandstone that is the manifestation of the Cambridge Arch three miles east from the facility. A low area with a northwesterly orientation can be seen to pass close to the center of the AOR.

The low area seen running northwest-southeast through the center of the AOR on the Berea Sandstone map reverses itself and appears as a southeast-plunging nose on the Onondaga Limestone structure. On the east edge of the AOR the contour lines are more closely spaced, but show a down-to-the-east monocline in place of the shallower Berea anticline. Evidence of the Cambridge Arch is tenuous.

The structural forms seen on the Onondaga Limestone structure are mimicked on the Dayton Formation structure. Whereas the relief across the breadth of the Onondaga Limestone nose was on the order of 20-25 ft., it is 15-20 ft. on the Dayton Formation surface and maintains the same orientation seen on the Big Lime. The dip on the Onondaga Limestone has a maximum rate of approximately 80 ft./mi., but on the Dayton Formation the dip is about 100 ft. per mile, at least part of which can be attributed to normal eastward thickening of all units.

At the center of the AOR, Buckeye Brine has drilled three wells. In order that all wells could, in the future, be tied to a reliable and repeatable datum, drilling and openhole wireline measurements utilized a ground level datum. The original surveyor's ground levels have been update with GPS to account for any differences due to excavation (ground leveling) prior to drilling. Baker-Hughes logs were run in all three wells, including:

No. 1 Adams - Industry-standard gamma ray, neutron, density, photo-electric, resistivity openhole logs were run from 5900 ft. to the logger's 7305 ft. total depth. A cased hole gamma ray-neutron log was run from 354-5900 ft., and a correlation gamma ray from surface to 354 ft.

No. 2 Adams - A gamma ray, neutron, density, photo-electric, resistivity openhole log suite was run from 5930 ft. to the logger's 7016 ft. total depth. A cased hole gamma ray-neutron log was run from 85-5930 ft., and a correlation gamma ray from surface to 85 ft. Advanced acoustic and image logs were acquired in the bottomhole interval.

No. 3 Adams - Gamma ray, neutron, density, photo-electric, and resistivity openhole logs were run in the intermediate hole from 838 ft. to the logger's 6031 ft. total depth, and in the bottomhole interval from 6048-7135 ft. Advanced acoustic, image, and nuclear magnetic resonance logs were acquired in the bottomhole section.

Of primary interest is a structural comparison of the No. 1 and No. 3 Adams wells which shows the No. 1 to be low to the No. 3. It is likewise low to the No. 2 Adams. Formation tops and subsea values are shown in the following Table 2.

	7177 #1 Adams	Subsea	7241 #3 Adams	Subsea	7178 #2 Adams	Subsea
Datum	775		785		800	
Berea	807	*-32*	812	*-27*	821	*-21*
Big Lime	2372	*-1597*	2388	*-2603*	2396	*-1596*
Packer Shell	3806	*-3031*	3604	*-2819*	3620	*-2820*
Clinton	3660	*-2885*	3694	*-2909*	3674	*-2874*
Queenston	3805	*-3030*	3821	*-3036*	3822	*-3022*
Trenton	5210	*-4435*	5202	*-4417*	5212	*-4412*
Gull River	5860	*-5085*	5842	*-5057*	5842	*-5042*
Lower Chazy	5910	*-5135*	5894	*-5109*	5900	*-5100*
Wells Creek	absent		5922	*-5137*	5928	*-5128*
Beekmantown	5920	*-5145*	absent		absent	
Rose Run	5982	*-5207*	5960	*-5175*	5970	*-5170*
Copper Ridge	6098	*-5323*	6038	*-5253*	6052	*-5252*
Copper Ridge "B"	6300	*-5525*	6233	*-5448*	6254	*-5454*
Lwr Copper Ridge	6320	*-5545*	6252	*-5467*	6272	*-5472*
Conasauga	6560	*-5785*	6468	*-5683*	6496	*-5696*
Rome	6669	*-5894*	6583	*-5798*	6614	*-5814*
Mt. Simon	7215	*-6440*	7125	*-6340*	NR	-
Precambrian	7295	*-6520*	NR		NR	
Logger TD	7305	*-6530*	7135	*-6350*	7007	*-6207*

Table 2 Formation top and subsea elevations for the Buckeye Brine Nos. 1, 2, and 3 Adams wells

The No. 2 and No. 3 Adams wells, north of the No. 1 Adams, are structurally higher than the No. 1 well (Figure V.B.8.05. At the top of the Mt. Simon, the deepest common horizon in the No. 1 and No. 3 wells, the No. 1 is 100 ft. deeper, this in a surface distance of 921 ft. It is a value out of line with what is know about the relatively flat strata in the AOR. Wireline depths in all three wells repeat well, and relative ground level elevations are considered reasonable when looking at the land. The wellbore was reasonably straight (<3 degrees in the aggregate) through the intermediate hole, but no deviation surveys were taken in the bottomhole section.

The immediate impression from the subsea differences is that a fault is at play. However, a careful comparison of the tops and unit thicknesses from the Berea to the Mt. Simon shows that the most of the units in the No. 1 well are thicker than those in the No. 3 well, and that the rates of thickening vary considerably, but are typically less than 1.5%. Exceptions, for example, are noted:

4. In the No. 1 Adams the lower half of the Conasauga thickens and the upper half thins, such that in the No. 1 well there is a net 5% thinning (Figure V.B.8.06.

5. The Lower Copper Ridge in the No.1 Adams thickens slightly through most of the section relative to the No. 3 well, but the thickening is pronounced in the lowermost 40 ft. of the unit (Figure V.B.8.07. Overall the Lower Copper Ridge section in the No. 1 Adams is 11% thicker than in the No. 3 Adams. There does not appear to be any repeating of section in the No. 1 well, nor are there any flags on the No. 3 Adams image log that suggest faulting as a means of accounting for the short section.

A close examination of the well logs for the No. 1, 2, and 3 Adams wells reveals no missing sections as in the case of a normal fault, nor are there any repeated sections as would be the case for a reverse fault. Image logs In the nearby Nos 2 and 3 Adams wells show small scale fracturing, much of it drilling-induced, but nothing that resembles a fault zone.

Overall, the evidence is that at the No. 1 Adams location there appears to have been slow subsidence of varying rates over a very prolonged period of time, in the manner of a growth fault as commonly seen in the Gulf of Mexico Salt Dome Province. Growth faults occur contemporaneously with sedimentation and may leave little or no trace of movement other than differences in bed thickness across the plane or zone of movement (Figure V.B.8.08). Growth faults are sometimes referred to as healing or accommodation faults, though the application of the terminology must be made carefully and well explained.

References cited:

Mason, G, 1999, Structurally related migration of hydro-carbons in the central Appalachian Basin of eastern Ohio, in Into the new millennium: the changing face of exploration in the Knox play: Sixth Annual Fall Symposium Proceedings, Akron, Ohio, Ohio Geological Society, p. 20-32.

Wickstrom, L. H., Riley, A. R.., Spane, F. A., McDonald, Jas., Sclhucher, E. R., Zody, S. P., Wells, J. G., Howatt, E., 2011, Geologic Assessment of the Ohio Geological Survey No. 1 CO_2 well in Tuscarawas County and Surrounding Vicinity: ODNR, Division of Geological Survey, Columbus, Ohio, 97 p.

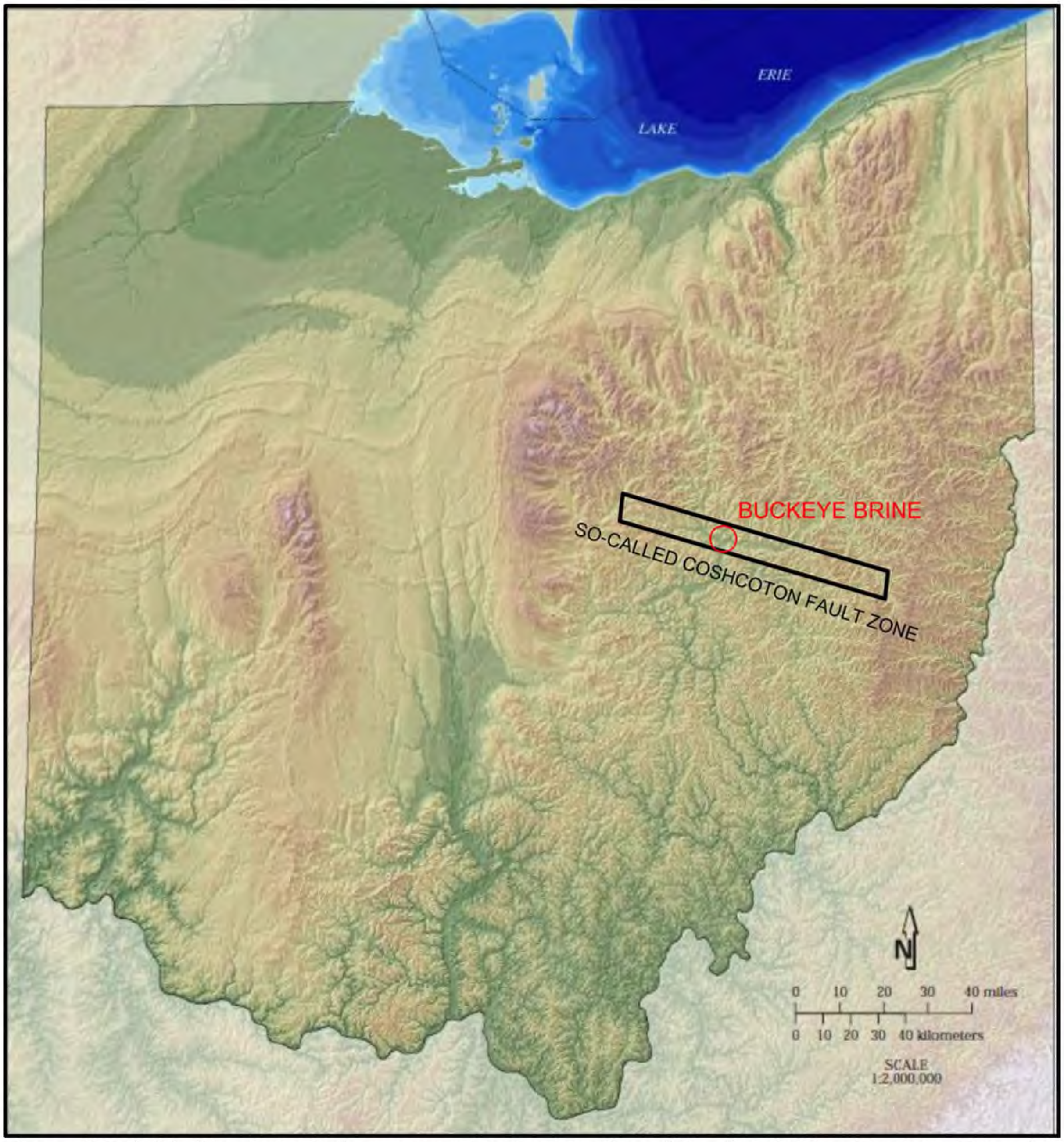


Figure II.B.8.01 Shaded relief map showing the location of the Cambridge Fracture Zone (aka Coshcoton Fault Zone) as defined by surface lineaments.

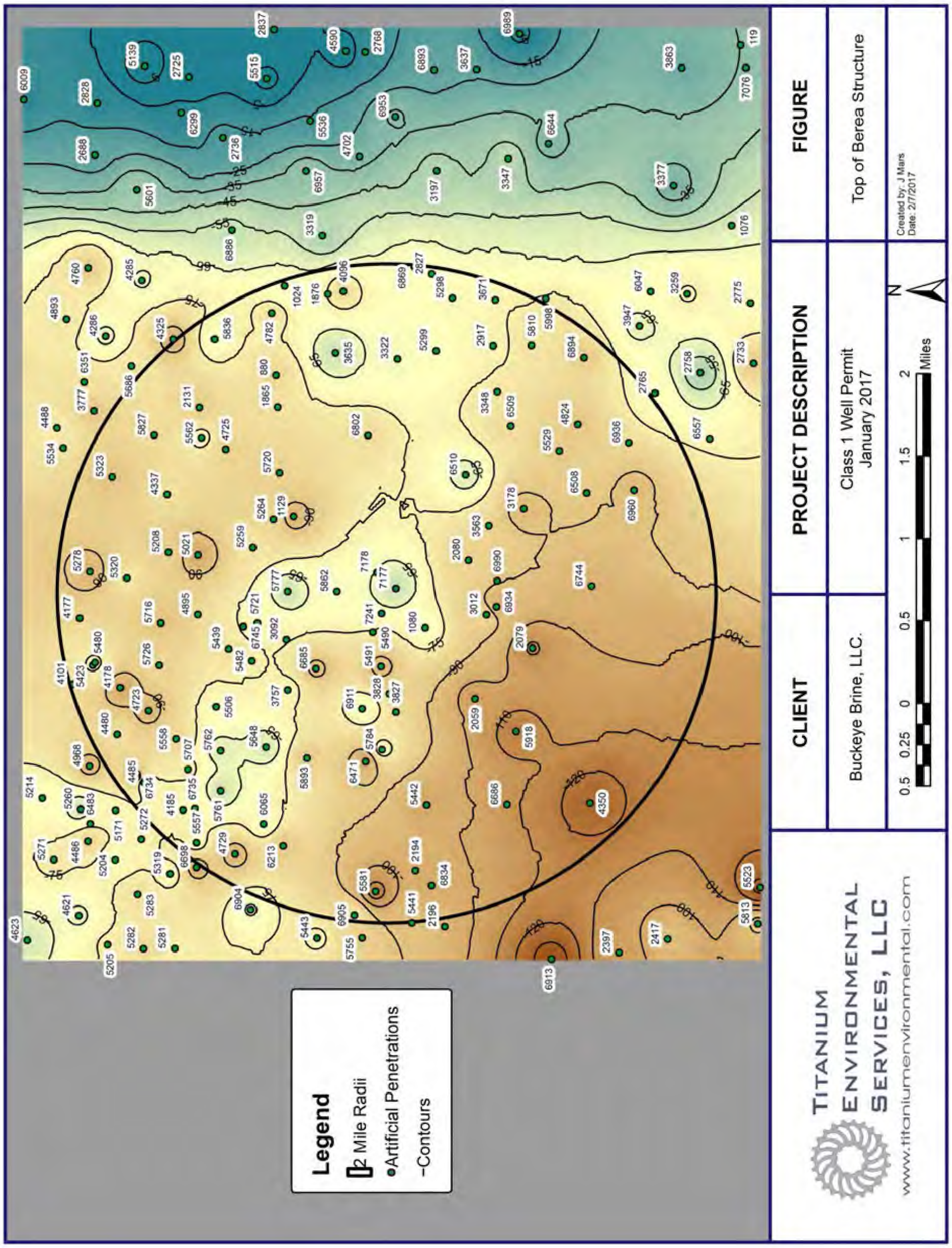


Figure II.B.8.02 - Structure map on the top of the Berea Sandstone

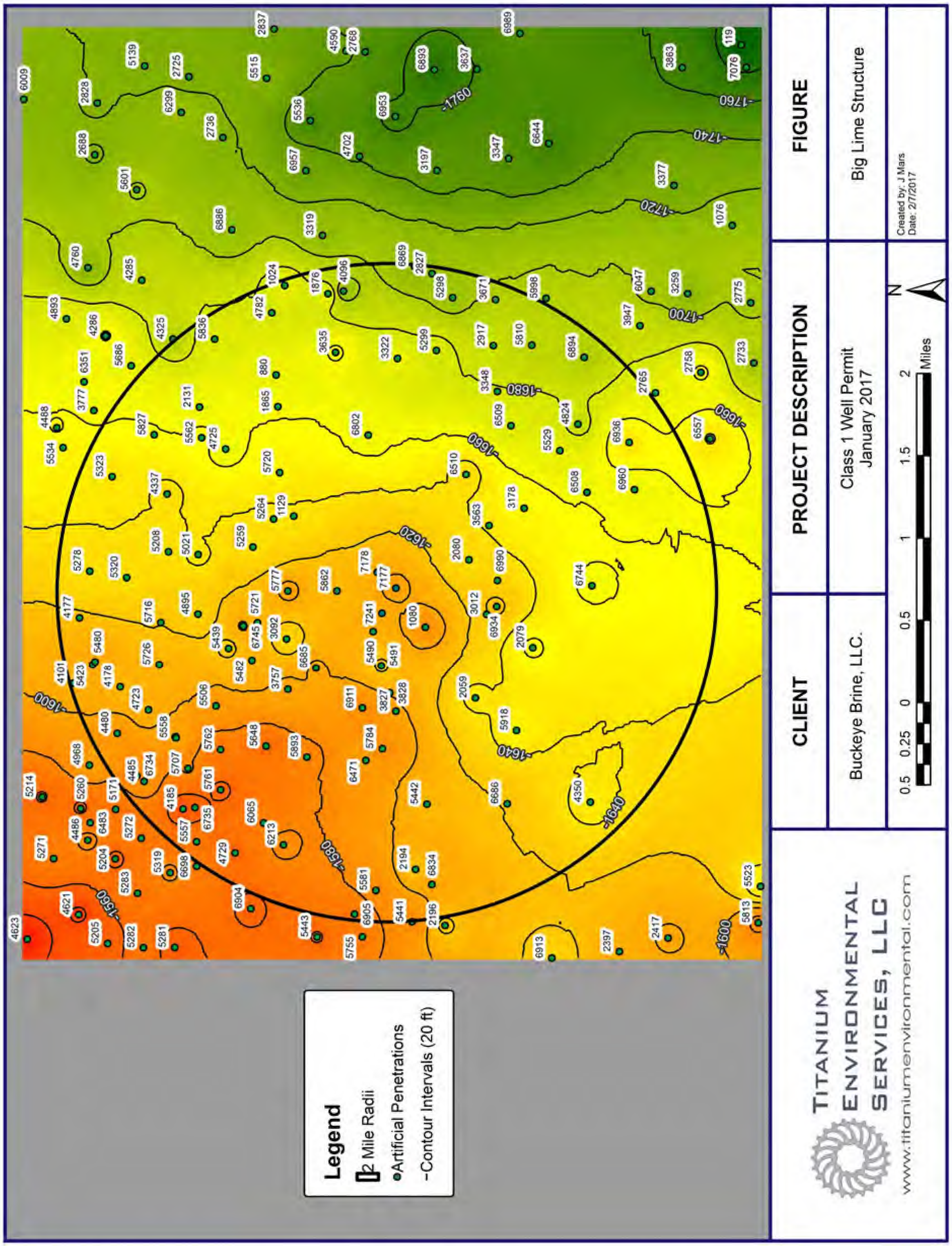


Figure II.B.8.03 - Structure map on the top of the Onondaga Limestone (Big Lime)

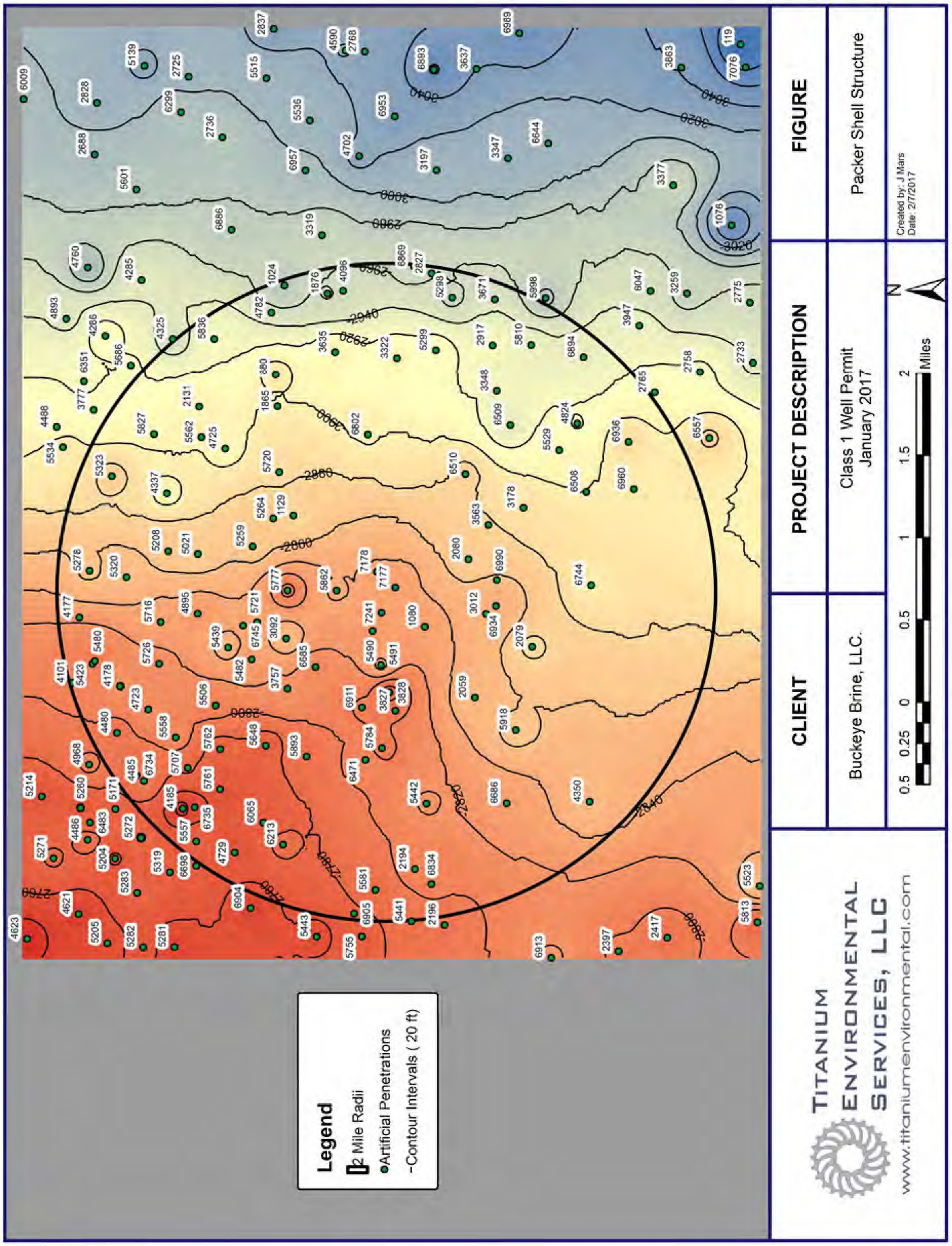


Figure II.B.8.04 - Structure map on the top of the Dayton Formation (Packer Shell)

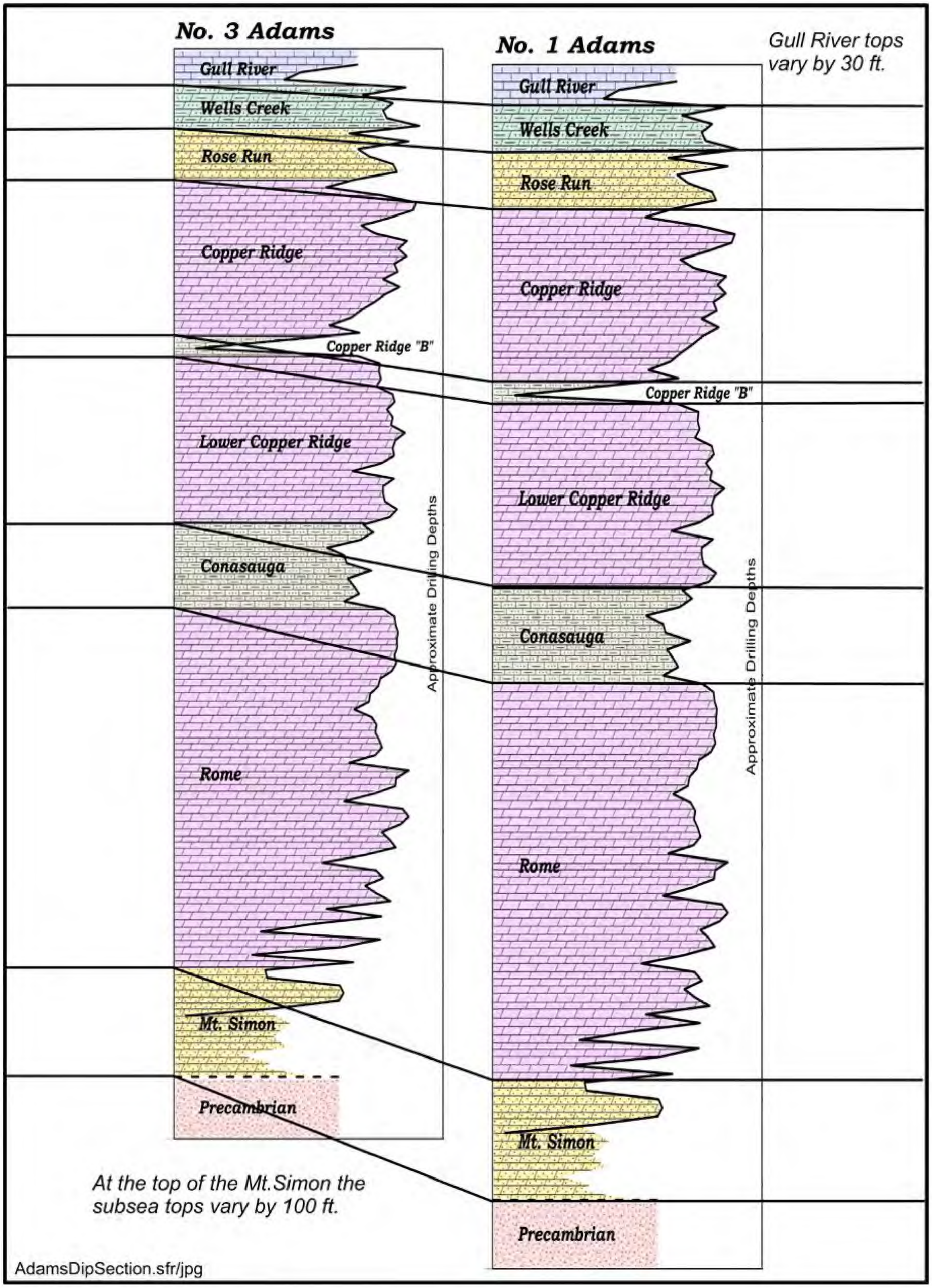

No. 3 Adams
No. 1 Adams
Gull River tops vary by 30 ft.
Gull River
Wells Creek
Rose Run
Copper Ridge
Copper Ridge "B"
Lower Copper Ridge
Conasauga
Rome
Mt. Simon
Precambrian
Approximate Drilling Depths
At the top of the Mt.Simon the subsea tops vary by 100 ft.
AdamsDipSection.sfr/jpg

Figure II.B.8.05 - Representational cross section showing structural differences between the No. 3 Adams (left) and No. 1 Adams (right)

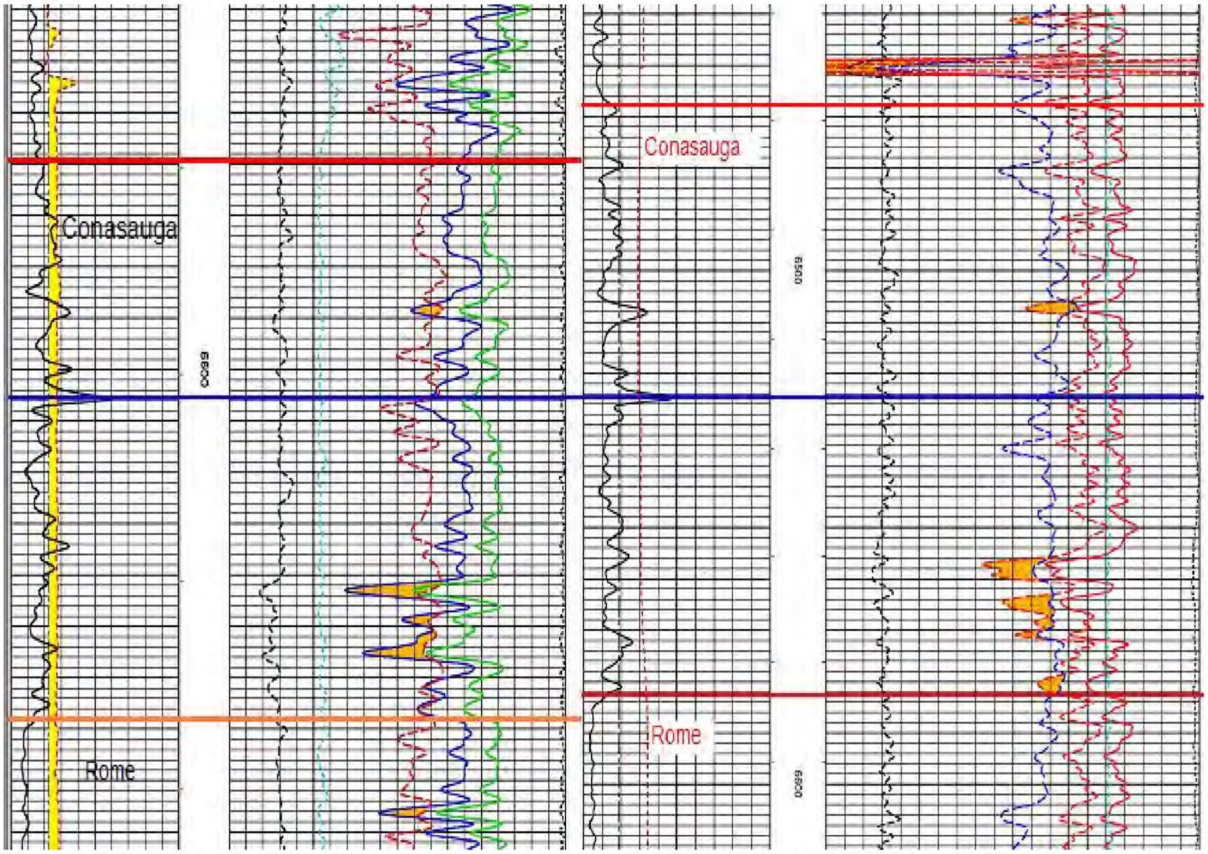


Figure II.B.8.06 - Comparison of differing rates of thickening and thinning in the Conasauga in the No. 1 Adams (left) and No. 3 Adams (right)

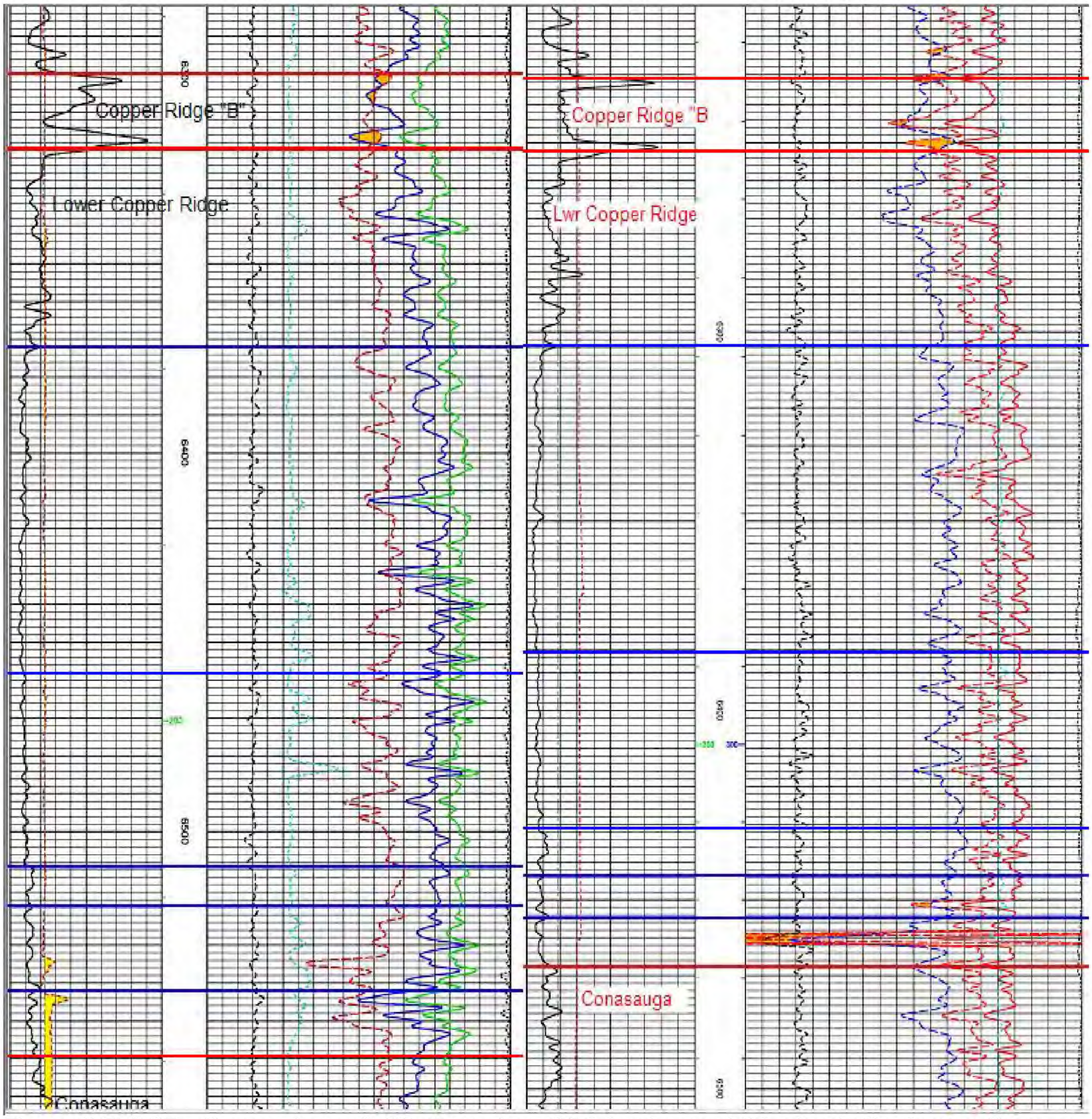


Figure II.B.8.07 - Comparison of differing rates of thickening and thinning in the Lower Copper Ridge in the No. 1 Adams (left) and No. 3 Adams (right)

This illustration shows two variations on vertical displacement of sedimentary rocks. On the left the displacement happened at once, fracturing all beds at the same time and effecting all beds equally. To the right the displacement has happened continually over a long period. The displacement is most evident in the lower beds; the effect on shallow beds is minimal. The displacement is some combination of fracturing, accommodation by sedimentation, and flexure.

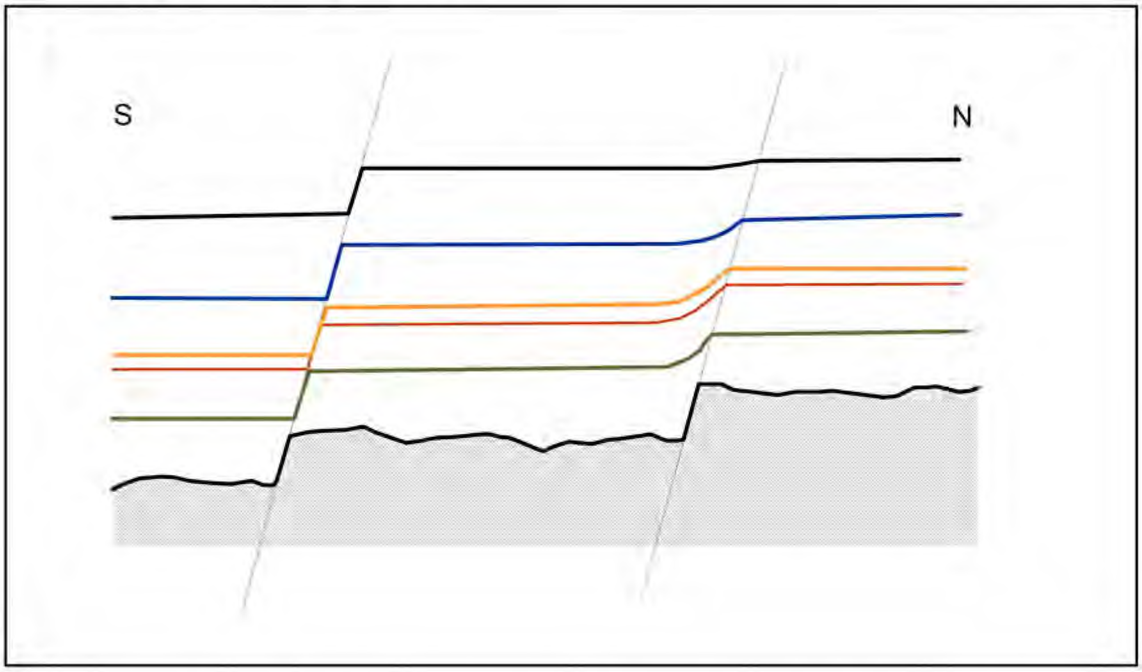


Figure II.B.8.08 - Cross section illustrating the difference between a late-occurring normal fault (left) and a growth or accommodating fault (right)

II.C SEISMICITY, SEISMIC RECONNAISSANCE AND INTERPRETATION

II.C.1 REGIONAL AND LOCAL SEISMIC MONITORING

Regional seismic monitoring in Ohio is carried out by a number of State and Federal agencies, both scientific and regulatory.

Since 1999 the Ohio Geological Survey, in cooperation with the Ohio Emergency Management Agency, has operated the Ohio Seismic Network, also known as OhioSeis. It is Ohio's oldest wide-ranging seismic monitoring system that currently includes 27 stations deployed primarily at and operated by colleges and universities (Figure II.C.1-01). The Geological Survey coordinates the network and provides data analysis. This Ohio Geological Survey is also part of the U.S. Geological Survey Advance National Seismic System (ANSS) and is a host site for station ACSO.

CODE	LOCATION	LATITUDE	LONGITUDE	ELEV. (M)
ACEO	Jefferson	41.7387	-80.7706	292
ACSO	Alum Creek	40.2321	-82.982	282
BCSO	Carroll	39.7941	-82.5198	258
BGSO	Bowling Green	41.3794	-83.6399	208
BGFO	Huron	41.397	-82.594	185
BHSO	Botkins	40.4696	-84.1763	305
BTCO	St. Clairsville	40.0772	-80.9659	372
CLEO	Cleveland	41.5131	-81.613	205
COWO	Wooster	40.8095	-81.9368	328
CSCO	Springfield	39.8956	-83.7974	323
ECCO	Piqua	40.158	-84.2115	289
GPDO	Montville	41.5831	-81.0717	378
KSTO	New Philadelphia	40.4709	-81.4042	249
KSUO	Kent	41.151	-81.351	346
LCCO2	Kirtland	41.6393	-81.3572	245
LECO	Painesville	41.7175	-81.253	204
MACO	Marietta	39.4166	-81.4491	193
MOSO	Butler	40.6115	-82.3827	370
MUCO	Alliance	40.904	-81.11064	371
OGSO	CLOSED Columbus	40.0568	-82.9654	268
OSLO	Lima	40.7375	-84.0265	285
OSMO	Mansfield	40.797	-82.579	397
OSUO	Columbus	39.9981	-83.0109	226.1
OUAO	Athens	39.3226	-82.0997	194
SSUO	CLOSED Portsmouth	38.7306	-82.9931	162
UOCO	Cincinnati	39.1333	-84.5187	266
UTLO	CLOSED Toledo	41.6594	-83.618	178

CODE	LOCATION	LATITUDE	LONGITUDE	ELEV. (M)
WSCO	Celina	40.5467	-84.5092	270
WSDO	Dayton	39.7826	-84.0633	289
YSUO	Youngstown	41.1043	-80.648	271

The ODNR Division of Oil & Gas Resources Management (DOGRM) operates the OhioNET Seismic Network, which consists of 31 seismic monitoring stations. The stations are located in Counties throughout Ohio with oil and gas operations. They detect micro-seismic events and transmit data in real-time to DOGRM. Once alerted, the data is analyzed to determine if the seismic event is natural or whether there could be a potential relationship with human activities.

CODE	COUNTY	LATITUDE	LONGITUDE	ELEV. (M)
OHN1 (ACSOL)	Mahoning	40.979	-80.6441	377
OHN3	Mahoning	40.9621	-80.6712	325
OHN5	Mahoning	40.949	-80.6648	355
OHM6	Washington	39.3844	-81.3434	261
OHM7	Washington	39.3668	-81.3402	253
OHM8	Washington	39.3681	-81.3693	256
WES1	Washington	39.4303	-81.5112	260
WES2	Washington	39.403	-81.4772	188
OHN9	Washington	39.4091	-81.3669	247
OHU1	Muskingum	39.9545	-81.8216	303
OHH2	Harrison	40.2018	-81.2004	341
OHH3	Harrison	40.248	-81.2679	320
OHH5	Harrison	40.2492	-81.0591	303
OHR1	Meigs	38.9356	-81.7864	188
OHR2	Meigs	38.9725	-81.7891	180
OHT2	Tuscarawas	40.2913	-81.5982	266
OHT5	Tuscarawas	40.4053	-81.3129	267
OHB1	Trumbull	41.2768	-80.8954	278
OHB2	Trumbull	41.4618	-80.7216	315
OHB3	Trumbull	41.2956	-80.6894	335
OHB4	Trumbull	41.2382	-80.6277	353
CES1	Athens	39.1982	-81.7469	239
CES2	Athens	39.2509	-81.7894	221
CES3	Athens	39.2471	-81.7159	204
ORR1	Muskingum	39.9952	-81.8297	251

CODE	COUNTY	LATITUDE	LONGITUDE	ELEV. (M)
ORR2	Muskingum	39.9797	-81.8025	280
ORR3	Muskingum	39.9717	-81.8538	231
CLE1	Guernsey	40.0268	-81.5031	286
CLE2	Guernsey	40.0419	-81.5049	272
CLE4	Guernsey	40.0144	-81.4261	272
HHE1	Pickaway	39.6114	-83.049	222

II.C.2 LOCAL SEISMICITY

The Ohio Division of Geological Survey's OhioSeis catalogs earthquakes in Ohio and has actively monitored for seismic events since 1999. As of 2014 OhioSeis listed no instrumentally recorded natural or induced seismic events greater than magnitude 2.0 within 30 miles of the AOR (Figure II.C.2-01: ODNR Recent Earthquake Epicenters in Ohio Map).

Since 2013 DOGRM has deployed portable seismic stations to monitor for induced seismic events associated with oil and gas well completion operations as well as Class II disposal operations. The Division currently maintains an array of 31 stations. To date, it has not reported any seismic events greater than magnitude 2.0 within a 30-mile radius of the AOR.

Buckeye Brine (Buckeye) installed its own 3-station network around its three Class II wells beginning in September 2013. The processed data from Buckeye's network was delivered to DOGRM for a period of 18 months through February 2016. During that period neither Buckeye's seismic processor nor DOGRM identified any seismic activity attributable to Buckeye's ongoing injection operations. Buckeye has continued to collect and archive data from its network since March 2016.

At the onset of operation of Buckeye's No. 3 Adams Class II injection well (API #34031272410000), DOGRM installed a seismic station on adjacent State-owned property for the purpose of providing additional monitoring over and above what was being carried out by Buckeye. For the duration of this monitoring, no induced seismicity attributable to Buckeye's injection wells was recognized by DOGRM.

II.C.3 SEISMIC PLAN

The seismic plan utilized two crossing lines with a total line length of 9.33 miles to effectively cover a 2-mile radius around the Buckeye facility.

The project area was 2 miles north of the city of Coshocton (county seat) and on the near north side of US Rt. 36.

II.C.3.a LINE LAYOUT AND COVERAGE

The purpose of the seismic program was to help define the repose of Cambrian and Precambrian strata in the vicinity of the project area. Two intersecting lines were proposed (Figure

II.C.3.a-01). The lines were acquired with a combination of dynamite and vibroseis energy sources. All stations on both lines were recorded live for increased fold. Near equal length on both sides resulted in higher stack fold near the center of the lines where the Buckeye Brine facility is located. Cultural factors influenced the line layouts.

A 4.85-mile north-south line designated as BB-KTC-16-2D-1 was run cross-country and crossed the Buckeye facility. It took advantage of utility easements and open fields. There were short skips for pipelines, roads, the airport runway, and power lines.

A 4.48-mile west-east tie line designated as BB-KTC-17-2D-2 was also run cross-country and through the Buckeye facility. There were skips on the north side of Canal Lewisville but vibe points were used to fill in where possible.

II.C.3.b PROCESSING

The seismic processor for this project was Exploration Development, Inc. (EDI), Parker, CO (http://www.exdvpinc.com/). Their primary data processing software is the Mercury International Technology (MIT) iXl package. They also use Green Mountain Geophysical refraction statics software and various support modules written internally. Exploration Development, Inc. (EDI) has been processing seismic throughout Ohio since 1992.

Processing Flow

1. Load Data
2. Geometry Update and Trace Edit
3. Gain Recovery
4. Surface Consistent Deconvolution
5. CDP Sort
6. Zero Phase Spectral Whitening
7. Refraction Statics
8. Velocity Analysis – 2 Passes
9. NMO Corrections
10. Muting – Average NMO Stretch 1.4 to 1
11. Surface Consistent Statics – 2 Passes
12. Trace Balance
13. CDP Trim Statics
14. Dip Moveout , INMO, Vel Analysis, NMO
15. Split Frequency Trim Statics
16. Common Depth Point Stack
17. Trace Balance
18. Migration

19. Noise Subtraction
20. Time Variant Spectral Whitening
21. Further Enhancement (FX Decon / FK)
22. Trace Balance

Additionally, step 14 was replaced by Prestack Time Migration and then finalized as above.

The observer's log in the field files recorded ranges for dynamite shots and vibroseis so that the processor could indicate the various energy sources on the seismic section (Figure 11.C.3.c-01 and Figure II.C.3.c-02). Prints were plotted at 18 traces/inch and 15 inches/second (Figures II.C.3.c-03, II.C.3.c-04, II.C.3.c-05 and II.C.3.c-06).

The No. 1 Adams (API #34031271770000) synthetic was used for correlation. To match the synthetic seismogram to the seismic data, the processor cross correlated the data sets to phase match the seismic to the synthetic. This is the same process used to match the vibroseis data to the dynamite data.

Line Name	BB-KTC-16-2D-1	BB-KTC-17-2D-2
County	Coshocton	Coshocton
Township	Keene/Tuscarawas	Keene/Tuscarawas/White Eyes
Acquisition Date	12/16	2/17
SP	1101-1333	2101-2315
CDPS	202-666	202-630
Miles	4.85	4.48
Receiver Interval	110'	110'
Source Interval	110'	110'
Source	dynamite/vibroseis	dynamite/vibroseis
Sample Rate	1 ms	1 ms
Record Length	4000 ms	4000 ms
Processed Date	12/13/16	2/7/17
Bearing of Line	N to SE	W to E

II.C.4 SEISMIC INTERPRETATION METHODS

The lists below are of all the processed versions provided by EDI that were reviewed for interpretation.

BB-KTC-16-2D-1	**BB-KTC-17-2D-2**
bb161bx20	bb172bx20orig
bb161es20	bb172es20orig
bb161fk00	bb172fk00orig
bb161fk80	bb172fk80orig
bb161nsnt	bb172nsntorig
bb161ntfx	bb172ntfxorig
bb161raws	bb172rawsorig
bb161tw00	bb172tw00orig
pms161bx20	bb172bx20
pms161fk00	bb172es20
pms161fk80	bb172fk00
pms161nsnt	bb172fk80
pms161ntfx	bb172nsnt
pms161pmst	bb172ntfx
pms161tw00	bb172raws
	bb172tw00
	bb172m80
	bb172m90
	bb172m100
	bb172m110
	bb172m120
	psm172bx20
	psm172fk00
	psm172fk80
	psm172nsnt
	psm72ntfx
	psm172pmst
	psm72tw00

Interpretation was performed in GeoGraphix's SeisVision software and on paper prints of migrated, normal, and reverse polarity data. The No. 1 Adams (API# 34031271770000) synthetic was used for identification and interpretation of key reflectors on BBC-KTC-16-2D-1 and BB-KTC-17-2D-2. Analysis of individual reflectors was performed to enhance details in the seismic waveform and amplitude. Waveforms exhibit different character with different frequencies and with different geology and can confirm formation thickness and geologic sequence. Isochron mapping was compared to known geology.

Detailed wavelet character was interpreted by understanding the relationship of the local geology to the seismic information, regional geology and the frequency content of the seismic data. Time picks from reflection interpretations were then used to construct time-structure maps to show local geological relationships between the wells and for clues to paleotopography.

II.C.5 INTERPRETATION OF DATA

BB-KTC-16-2D-1 and BB-KTC-17-2D-2 were examined for evidence of deformation or faulting in the sedimentary section that could indicate a compromise of the seal in the confining layers. The Cambridge Arch was not observed on the seismic as it is too far east of the line locations and Area of Review (AOR).

Key formation horizons were picked on both lines. These included the Big Lime, Packer Shell, Trenton, Gull River, Beekmantown, Rose Run, Lower Copper Ridge, Mt. Simon, and Precambrian. Various of these horizons were later used to construct stratigraphic sections (arbitrary datums), and structure and isochron maps.

Structure maps were constructed from well control for the top of the Berea sandstone, Big Lime, and Packer Shell for later comparison to the seismic. Although some patterns were noted, it should be said that the control for the mapping was considered fair owing to the suspect nature of the ground level elevations and their effect on calculated subsea elevations. Interpretation of the seismic-generated horizons away from the actual lines themselves can be misleading. In all, the comparisons were considered too tenuous to draw meaningful conclusions. All figures identified in this section of the report are provided in Appendix II.

Figures - BB-KTC-16-2D-1

II.C.5-01 migration 80 Hz, normal polarity, grayscale

II.C.5-02 migration 80 Hz, normal polarity, wiggle trace, color amplitude

II.C.5-03 migration 80 Hz, normal polarity, wiggle trace, color amplitude, flattened Trenton

II.C.5-04 migration 80 Hz, normal polarity, wiggle trace, color amplitude, flattened Gull River

II.C.5-05 migration 80 Hz, normal polarity, wiggle trace, color amplitude, faults

II.C.5-06 migration 80 Hz, normal polarity, color amplitude, faults

II.C.5-07 migration 80 Hz, normal polarity, color amplitude, faults, compressed section

On BB-KTC-16-2D-1, the most evident structure is a basement feature on the north end from SP 1119-1140 that is herein referred to as the "Airport Dome". On the initial Figure II.C.5-5 presentation and subsequent iterations, the feature appears as a pop-up structure, the result of compression that occurred in late Precambrian, with some slow accommodation of stress that impacted lower and middle Cambrian sedimentation. The faults are not seen to extend above the base of the Precambrian.

Across the central and southern portions, line BB-KTC-16-2D-1 exhibits minor undulations, without any definable basement influence. The seismic failed to reveal faulting or vertical discontinuity between the Adams wells.

Figures - Line BB-KTC-17-2D-2

II.C.5-08 migration 80 Hz, normal polarity, grayscale
II.C.5-09 migration 80 Hz, normal polarity, wiggle trace, color amplitude
II.C.5-10 migration 80 Hz, normal polarity, wiggle trace, color amplitude, flattened Trenton
II.C.5-11 migration 80 Hz, normal polarity, wiggle trace, color amplitude, flattened Gull River

The data quality for line BB-KTC-17-2D-2 was considered fair to good in comparison to line BB-KTC-16-2D-1. It was acquired primarily through the Tuscarawas River valley where, as previously noted in Section II.C.3d, the weathered zone consisted for the most part of up to 175 ft. of unconsolidated sand and gravel valley fill. A back-filled portion of the Erie Canal and its feeder ponds are thought to have been especially detrimental to those portions of the line that are included in the intervals from SP 2101-2150 and SP 2230-2270.

The Precambrian surface shows some undulation that is considered to be within the range of normal. The most notable feature is on the west end of the line where there appears a down-to-the-west flexure contained in the interval SP 2165-2170 (Figure II.C.5-14), after which the PC surface gradually regains its previous time elevation by the west end of the line.

The Cambrian and Ordovician sedimentary section is either flat or, on the west end of the line, subtly mimics the underlying Precambrian topography (Figure II.C.5-12). None of the units appear faulted so as to compromise the sealing capability of the designated confining layer.

There is some fabric to the Precambrian section. This may change in appearance from presentation to presentation, enough so that it cannot be determined if the fabric is due to structure (folding and/or faulting), or changes in the rock character.

The data was used to construct time structure maps for the Trenton, Gull River, and Precambrian. Isochron maps were made for the Trenton-Precambrian and Gull River-Precambrian intervals.

Figures - Time Structure and Isochron Maps

II.C.5-12 Trenton Horizon, Time Structure Map
II.C.5-13 Gull River Horizon, Time Structure Map
II.C.5-14 Precambrian Horizon, Time Structure Map
II.C.5-15 Trenton - Precambrian Horizons, Isochron Map
II.C.5-16 Gull River - Precambrian Horizons, Isochron Map

Attachment D

I. Closure Plan and Cost Estimates

III.C.1. Well Closure Plan

III.C.1.a Well Plugging and Site Cleanup

Buckeye will follow the plugging procedure set forth in Attachment III.C.1. Unless the landowner has some use for the tankage and other infrastructure related to the well operations, Buckeye will remove the tankage and infrastructure to return the surface to condition satisfactory to the landowner. A cost estimate for the plugging of the Adams #4 Well is provided below (Table III.D.).

III.C.1.b. Post Closure Activity

Buckeye will continue quarterly sampling of the groundwater monitoring wells. Groundwater samples collected from the wells will be tested for the constituents indicated in the Groundwater Monitoring Plan that is in effect at the time of closure. The samples will be collected for one year following site closure. Buckeye will also perform modeling to predict when the pressure injection zone has declined to a level protective of the lowermost USDW with removal of the pressure caused by injection activity. A cost estimate for the plugging of the monitor wells and the post closure activities is provided below. (Table III.D)

Table III.D UIC Class 1 Waste Injection Well

Estimate of Closure Costs (Plugging and Abandonmen for Adams #4

Total Costs are based on 2020 costs and adjusted to Jan 2023 dollars CPI

Calculation Date						1/9/2023
Well						Adams # 4
Permittee						
Job						
Plugging method						None
Avg Well Inside Diameter (in)						9.625
Top of injection Interval (feet)						5965
Pluggeg Back Total Depth (feet)						7000
Hazardous Waste Well						no
Calculated Mud Vol (bbl)						523
Calculated Cement Vol (ft3)						579
Consultant						
Preclosure and postclosure work						$ 8,500.00
Wellsite @ $1350/day						$ 13,500.00
Testing (MIT, pressure fall off)					*	$ 43,300.00
Workover rig, etc.						$ 30,000.00
Mechanical bridge plug						$ 8,800.00
Mud						$ 8,265.00
Cement						$ 20,424.00
Welding						$ 1,000.00
Extra charge for Haz Waste Well						
Consultant mark-up (12%)					*	$ 13,495
Subtotal						$ 147,284.00
Contingency (20%)						$ 29,457
		Total Well P&A Cost				
	$	-	$	-		$ 176,741
Well P&A Total in 2020 dollars	$	-	$	-		$ 176,741
Apply inflation from 10/2020 to 01/2023 (1.1398)	$	-	$	-		$ 201,449