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Stratigraphy Assessment Niagara Falls Air Reserve Station Niagara Falls, New York

Contract Number: F30617-94-D-0008-5021
Project No.: RVKQ 98-0904

July 1999

Prepared for:

United States Air Force Reserve Command
914th Airlift Wing

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Table of Contents

List of Illustrations

Figure | **Page**

List of Acronyms

AFRC	Air Force Reserve Command
AMSL	above mean sea level
AW	Airlift Wing
BAT	Bell Aerospace Textron
BGS	below ground surface
CEV	Civil and Environmental Engineering
cm/s	centimeters per second
DNAPL	dense nonaqueous phase liquid
E & E	Ecology and Environment, Inc.
IRP	Installation Restoration Program
NFARS	Niagara Falls Air Reserve Station
UST	underground storage tank
VOCs	volatile organic compounds

1 Introduction

E & E
Ecology and Environment, Inc.

AFRC
Air Force Reserve Command

AW
Airlift Wing

NFARS
Niagara Falls Air Reserve Station

BAT
Bell Aerospace Textron

IRP
Installation Restoration Program

BGS
below ground surface

This Stratigraphy Assessment is submitted by Ecology and Environment, Inc. (E & E), to the United States Air Force Reserve Command (AFRC) 914th Airlift Wing (AW) under Contract Number F30617-94-D-0008, Delivery Order Number 5021, Project Number RVKQ 98-0904.

The overall objective of this project was to investigate and provide a detailed description of the bedrock stratigraphy and related groundwater hydrology to create a conceptual model of the Niagara Falls Air Reserve Station (NFARS) and adjacent areas. The focus of this project was to determine if a stratigraphic correlation can be made between NFARS and the Bell Aerospace Textron (BAT) site; and to determine if similar groundwater contaminants at NFARS could be migrating to the BAT site, thereby contributing to the groundwater contaminant plume existing at the site. Figure 1-1, based on an USGS topographic map last updated in 1980, has been included to show the location of NFARS with respect to the BAT site.

As part of this project, a deep bedrock monitoring well (MW10-1F) was installed at Installation Restoration Program (IRP) Site 10 to provide stratigraphic information and aid in the vertical characterization of contamination at the site. This well is screened from approximately 42 to 59 feet below ground surface (BGS) and currently is the deepest well at the installation. A report detailing the installation and findings of this well was submitted to AFRC on January 2, 1999.

The project also involved a thorough review of existing publications, site reports, assessments, well boring logs, rock cores, and other data pertaining to regional and local site history and stratigraphy.

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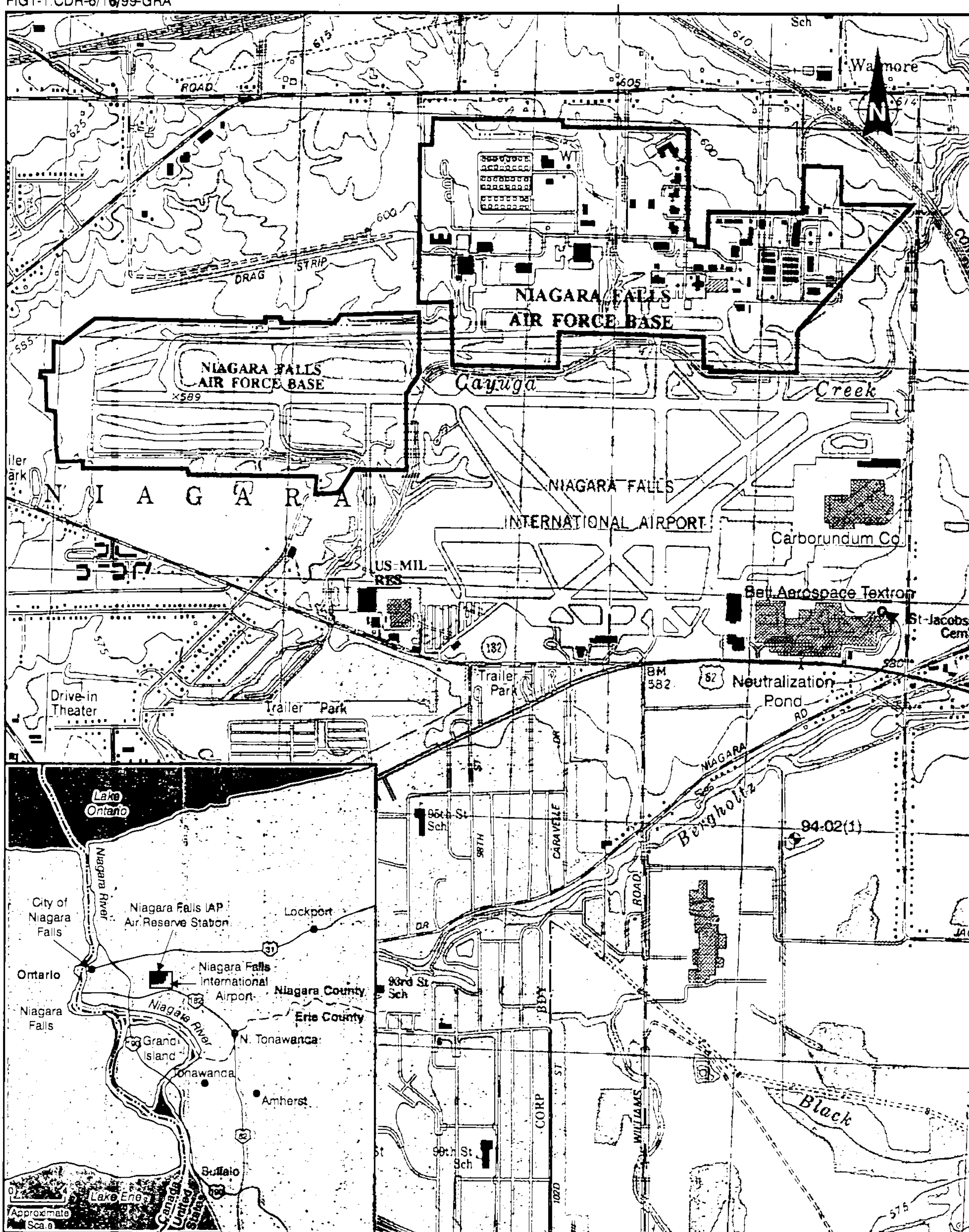
FIG1-1.CDR-6/16/99-GRA



SOURCE: USGS 7.5 Minute Series (Topographic) Quadrangle: Ransomville, NY, 1980; Tonawanda West, NY, 1980

SCALE 1:24,000

0 ½ 1 Mile

0 .5 1 Kilometer

Figure 1-1 REGIONAL LOCATION MAP

2 Site Background

2.1 Niagara Falls ARS

UST
underground storage tank

RFI
RCRA Facility Investigation

Under the IRP at NFARS, 14 sites were identified as potentially contaminated. These sites were evaluated and ranked to prioritize their need for investigative/remedial action. Based on this ranking, one site (old Site 13) was removed from the list. Environmental investigations at the remaining 13 sites began in 1983, and included, but were not limited to: monitoring well installation and groundwater monitoring; subsurface soil investigations; surface water and sediment investigations; geophysical investigations; underground storage tank (UST) removal; and the installation of remedial systems. Currently, seven of the sites (Sites 1, 2, 4, 6, 9, 11, and 12) have been, or are proposed to be, assigned no further action status; two sites (Sites 7 and 8) have been recommended for long-term monitoring; one site (Site 5) is undergoing a focused RCRA Facility Investigation (RFI); and three sites (Sites 3, 10, and 13) are currently undergoing corrective action.

Of these sites, Sites 3 and 10 are the focus of this detailed stratigraphic investigation because they are located closest to the BAT facility, exhibit some of the highest levels of groundwater contamination at the installation, and contain similar contaminants as those present at the BAT facility, thereby resulting in the greatest potential for hydrogeologic connection with the BAT. Corrective action in the form of groundwater capture and removal began in June 1998 at Sites 3 and 10, and the systems are currently active and closely monitored.

Site 3

Site 3 is located in the northeast corner of the installation and consists of an approximately 9-acre inactive landfill (see Figure 2-1). Prior to landfill construction, Site 3 was a low-lying marsh area along the west bank of Cayuga Creek. Reportedly, the area was filled with 8 to 10 feet of solid waste from the early 1950s until 1969. This waste, some of which was potentially hazardous,

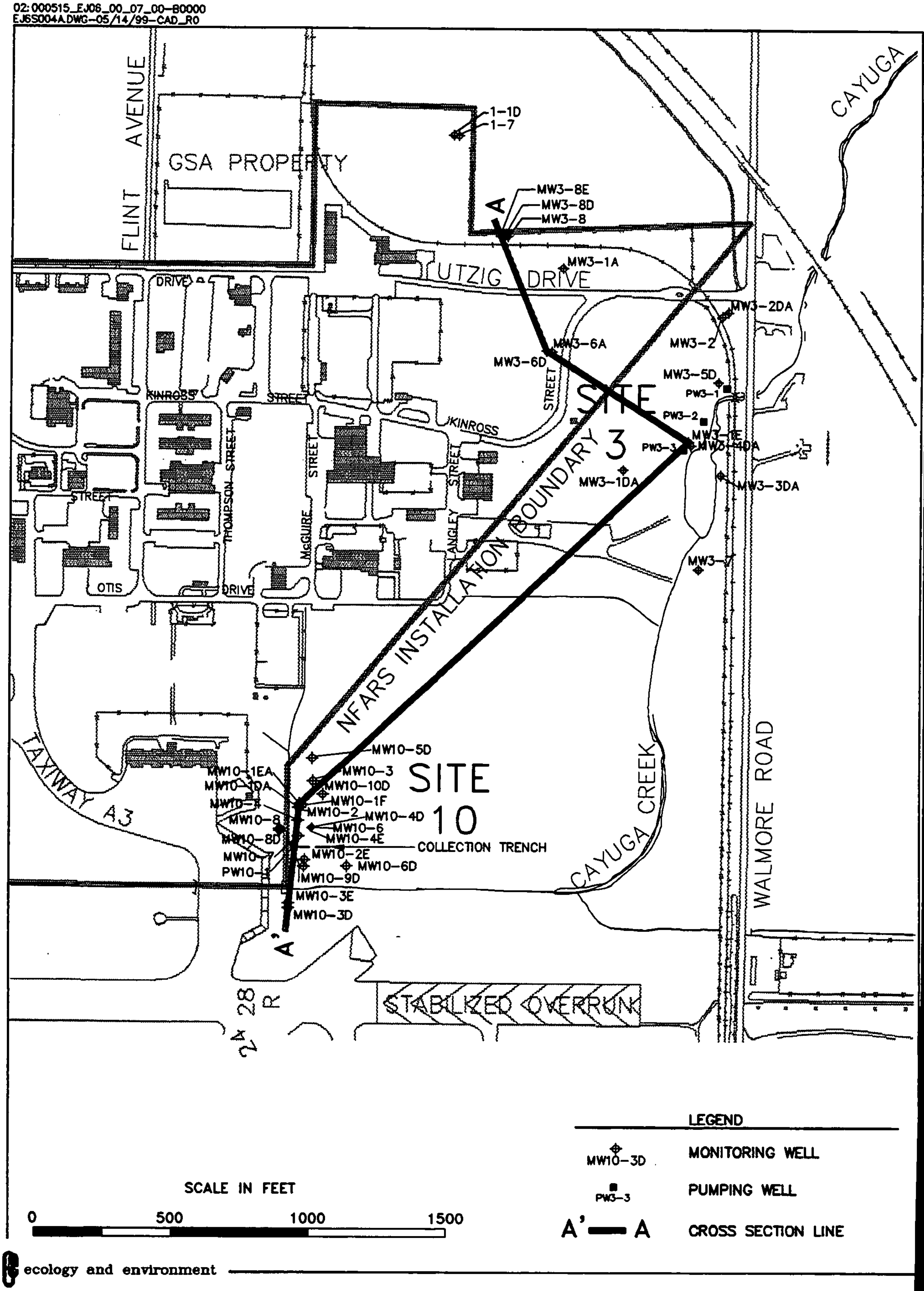


Figure 2-1 IRP SITES 3 AND 10
NIAGARA FALLS AIR RESERVE STATION
NIAGARA FALLS, NEW YORK

included base garbage, ash from coal stores, waste oil, shop wastes, batteries, scrap electrical parts from BAT, car parts, and trash from other locations. The waste was burned periodically until 1966 when air pollution regulations took effect, after which the waste was disposed of in trenches along the southern edge of the landfill. The entire area was regraded, covered with soil, and seeded in 1969. Currently, the site is a gently sloping grassy area with a few young deciduous trees and is crossed by Utzig Drive and Kinross Street.

Groundwater contamination is the primary environmental concern at Site 3. The average depth to bedrock at the site is 7 feet BGS; however, the depth is as little as 3 feet BGS near Cayuga Creek. On average, the depth to overburden groundwater is approximately 3 feet BGS, while the potentiometric surface of the shallow bedrock aquifer is at approximately 12 feet BGS. Overburden and bedrock groundwater flow directions are generally similar across the site and have been consistently from the northwest to the southeast toward Cayuga Creek. Although the landfill is in direct contact with the overburden groundwater, no significant impact has been detected in the overburden aquifer surrounding Cayuga Creek, nor in the surface water or sediment of Cayuga Creek itself. The main zone of contamination is the shallow bedrock aquifer. Contaminants of concern include the volatile organic compounds (VOCs) carbon disulfide, carbon tetrachloride, chloroform, chlorobenzene, 1,2-dichloroethene (cis- and trans- isomers), 1,1-dichloroethene, trichloroethene, and vinyl chloride from wells screened 8.5 to 24 feet BGS. Horizontal and vertical contaminant migration are limited at this site. In the shallow bedrock aquifer, no contamination has been detected in the southernmost well (MW3-1DA) and only very low levels of vinyl chloride and cis-1,2-dichloroethene have been detected across the creek in well MW3-3DA (see Figure 2-1). No contamination has been detected in six or more consecutive sampling rounds through September 1998 in the deeper bedrock monitoring wells (MW3-1E and MW3-8E), which are screened at approximately 30 to 40 feet BGS (E & E 1999a).

VOCs
volatile organic compounds

Site 10

Site 10 is located in the southeast corner of the installation (see Figure 2-1) and served as the principal fire training area during the late 1950s and early 1960s. A burn pit reportedly was constructed on the site with an earthen berm surrounding it; however, no evidence of this pit remains. The earthen berm was visible until 1997, when the area was covered with clean soil and regraded as part of a six-phase soil heating project conducted at the site (Montgomery

Watson 1998). A variety of combustible oils, solvents, and JP-4 fuel was burned in the alleged pit and then extinguished with fire-fighting foams during training exercises. Contaminants of concern include primarily the VOCs trichloroethene, 1,2-dichloroethene (cis- and trans- isomers), vinyl chloride, 1,1-dichloroethene, benzene, and toluene.

A storm water drainage ditch is located approximately 50 feet west of the former fire training area and flows intermittently from north to south into Cayuga Creek. This ditch primarily serves as a source of recharge to the overburden aquifer, but may seasonally act as a groundwater receptor. Overburden at Site 10 is approximately 8.5 feet thick across the site and the depth to overburden groundwater averages 5 feet BGS. Shallow and deep bedrock aquifers also exist at this site. Wells monitoring the shallow bedrock zone are screened from near the top of rock to approximately 25 feet BGS. Deeper bedrock wells are screened from approximately 30 to 40 feet BGS. As part of this investigation, one very deep bedrock monitoring well was installed with a screen depth of 44 to 59 feet BGS (see Section 3.3). The groundwater potentiometric surfaces measured in these wells indicate a direct connection between the overburden and shallow bedrock aquifers and a downward vertical gradient between the shallow and deep bedrock aquifers. No vertical gradient was observed between the deep and very deep bedrock zones, indicating that they are the same aquifer. During recent sampling events (March and September 1998), contaminant levels were similar in the overburden and shallow bedrock water-bearing zones in the source area. However, no contaminants were detected at depth in the deep and very deep bedrock wells in this area (E & E 1999a).

The horizontal gradients of the overburden, shallow bedrock, and deep bedrock water-bearing zones have been consistently to the south and south-southwest toward Cayuga Creek. However, no contamination has been detected south of the creek in monitoring wells MW10-3D or MW10-3E or in the surface water/sediment sample collected in the creek itself. Therefore, Cayuga Creek appears to act as a hydraulic boundary to overburden, shallow bedrock, and deep bedrock flow. Since the onset of groundwater collection and removal at Site 10, a cone of depression has been observed in the overburden and shallow bedrock water-bearing zones around the pumping well (PW10-1) (see Figure 2-1).

2.2 Bell Aerospace Textron

BAT owns and formerly operated a manufacturing facility in the Town of Wheatfield, New York, approximately 0.6 miles south of

DNAPL
dense nonaqueous phase liquid

NFARS at the intersection of Niagara Falls Boulevard and Walmore Road (see Figure 1-1). An RFI was conducted at the BAT site to characterize 27 solid waste management units and define the associated extent of contamination. The primary source of contamination identified at BAT resulted from the disposal of waste fluids (primarily chlorinated solvents) during the period 1949 to 1987 in a now-closed neutralization pond (see Figure 1-1). Releases from the unlined pond resulted in the development of a plume of dense nonaqueous phase liquid (DNAPL), and associated dissolved phase plumes in the overburden and bedrock groundwater (Golder Associates 1991).

The RFI report identified four stratigraphic zones, including one overburden and three bedrock zones (see Section 4.3). The DNAPL plume was found to be confined within the uppermost bedrock zone (Zone 1). The main dissolved phase plume also exists within this zone and is fed by the DNAPL. The Zone 1 dissolved phase plume was found to be roughly elliptical and extend 4,000 feet southward from the neutralization pond and have a maximum width of 3,600 feet. The main components of this plume are trichloroethene, 1,2-dichloroethene, vinyl chloride, and methylene chloride. The northern boundary of the plume is a short distance north of the neutralization pond and likely extends in this direction due to dispersion and interaction of the plume with subsurface drainage systems. Underlying this plume is an aquitard designated as Zone 2. The aquitard consists of an 8-foot-thick, unweathered, massive dolomite zone. As a result of the presence of this aquitard, only a very small plume was found to exist at depth in Zone 3 of the bedrock. Groundwater flow in the water-bearing zones is primarily to the south (Grasso and Smith 1993).

Extensive remedial actions have been implemented at the BAT site to remove contaminated groundwater associated with the dissolved phase plume and control the extent and impact of this plume.

2.3 Carborundum Abrasives

The Carborundum Abrasives facility, which has been manufacturing sandpaper and abrasive grain materials since 1968, is located between NFARS and BAT on Walmore Road (see Figure 1-1). According to a Site Inspection Report prepared for the facility (NUS Corporation 1990), three areas of environmental concern have been investigated at this facility:

- A 450-foot by 25-foot clay-capped landfill that was once an open dump used for the disposal of phenol and solid wastes;

- A surface impoundment used as a settling basin for storm and non-contact cooling waters discharged from the facility. Accidental spills have occurred in this impoundment, including 6000 gallons of phenol in 1978; and

- A temporary drum storage area.

The investigations conducted at the site revealed no evidence of significant groundwater contamination related to these activities. Wells drilled to auger refusal or into the uppermost few feet of weathered bedrock at the site have consistently shown no evidence of volatile organic contamination. In addition, a general overburden groundwater flow to the northeast was reported (Frontier Technical Associates Inc. 1994).

3 Stratigraphic Investigations

3.1 Literature Review

E & E conducted a thorough review of all available and pertinent reports, bulletins, and papers pertaining to the histories and stratigraphy of the sites involved. Section 6 includes a listing of all references cited in this report.

3.2 Interviews

E & E attended meetings and conducted interviews with key personnel from NYSDEC Region 9 and lead investigators/hydrogeologists from Golder Associates who are involved with the BAT site investigations and remediation. Information obtained from discussions with these contacts provided a more complete understanding of the hydrogeologic conditions of the study area and has been incorporated into this report.

3.3 Installation of Very Deep Bedrock Monitoring Well (MW10-1F)

In order to provide additional information on the deep bedrock stratigraphy and vertical extent of groundwater contamination, a very deep bedrock groundwater monitoring well (MW10-1F) was installed at IRP Site 10 (see Figure 2-1). This well was completed on October 19, 1998, and is screened from approximately 44 to 59 feet BGS. This new well was designated as a very deep bedrock well ("F" suffix) because other existing bedrock wells at the installation are designated as shallow bedrock ("D" suffix) or deep bedrock ("E" suffix). A complete report detailing the installation, slug testing, surveying, and sampling of MW10-1F was provided to 914th AW/Civil and Environmental Engineering (CEV) on January 12, 1999 (E & E 1999b). This report includes a drilling log and construction details for MW10-1F.

CEV
Civil and Environmental
Engineering

Well MW10-1F is located adjacent to overburden well MW10-2, shallow bedrock well MW10-1DA, and deep bedrock well MW10-1EA (see Figure 2-1). The "A" suffix represents a replacement well. The screen intervals of the four wells in this cluster are progressively deeper and do not overlap. Wells MW10-2 and MW10-1DA are among the most contaminated wells at this site. Therefore, in order to prevent the downward migration of contaminants, progressively telescoped steel casings were installed to isolate each water-bearing zone during the installation of each of the wells in this cluster.

cm/s
centimeters per second

Following installation and development, MW10-1F was sampled and analyzed for VOCs in October 1998. No site-related groundwater contaminants were detected. The slug test results indicated that the horizontal hydraulic conductivity of the very deep bedrock zone at this location is 2.9×10^{-5} centimeters per second (cm/s), which is lower than that of the median values of both the shallow (4.5×10^{-4}) and deep bedrock wells (5.6×10^{-4}) at the site.

Vertical hydraulic gradients were calculated at Site 10 based on water level measurements made on October 26, 1998. These calculations revealed that there was no gradient between the overburden and shallow bedrock zones (MW10-2/MW10-1DA) nor between the deep and very deep bedrock zones (MW10-1EA/MW10-1F). However, a 7% (0.07 feet per foot) downward vertical gradient was calculated between the shallow and deep bedrock zones (MW10-1DA/MW10-1E). These results indicate that a layer of relatively low porosity exists between the shallow and deep bedrock zones. The rock core descriptions and the groundwater analytical results, which show no contamination beneath the shallow bedrock zone at this location, support this conclusion.

3.4 Rock Core Inspections

On October 14, 16, and 29, 1998, E & E reexamined the rock core samples collected from selected wells at Sites 3 and 10 and from the BAT site. The rock cores inspected were MW3-8E, MW3-6D, MW3-1E, MW10-1F, and MW10-3E from NFARS (see Figure 2-1) and well 94-02(1) associated with the BAT site (see Figure 1-1). The 94-02(1) well is located between Walmore Road and Amy Drive, south of Niagara Road, approximately one-half mile south of the BAT facility. These rock cores were closely inspected and logged by the E & E project geologists familiar with the local stratigraphy. The cores were inspected with an emphasis on potential zones of correlation between wells and between sites. Particular attention was paid to zones of relatively high porosity resulting from zones of dense fracturing, solution cavities (vugs), and biostromes. Biostromes are zones of rock deposited primarily from the remains of sedentary marine organisms. The biostromes observed at NFARS primarily resulted from deposition by corals (mainly cladoporid and favositid corals [Brett et al 1995]). However, stromatolitic bioherms (circumscribed masses of rock formed from algal mounds) have been observed in rock cores from the western portion of NFARS.

Section 4 of this report summarizes the results of the rock core inspections and places them within the regional stratigraphic setting.

4 Stratigraphic Assessment

4.1 Regional Stratigraphy

The regional bedrock geology of Western New York is composed of the Niagaran Provincial Series, which includes the Medina, Clinton, and Lockport groups. These richly fossiliferous rocks generally consist of 400 feet of dolostone, limestone, shale, and sandstone (Brett et al 1995) that were deposited in shallow epeiric (continental interior) seas during the Silurian Age (approximately 408 to 438 million years ago). These strata have been gently folded to form an east-west trending, southward dipping monocline, providing the Niagara Falls region with a bedrock dip documented to range from 29 to 30 feet per mile (Zenger 1965; Fisher and Brett 1981; Yager 1993). Erosion of these dipping strata is responsible for the formation of the Niagara Escarpment, which is capped by the Lockport Group.

The Lockport Group consists of approximately 160 to 175 feet of massive- to medium-bedded, argillaceous (derived from clay-rich sediments) dolostone with minor amounts of limestone and dolomitic shale (Brett et al 1995) deposited during the Late Silurian Age (approximately 414 to 423 million years ago). A descriptive stratigraphic column of the Lockport Group is provided as Figure 4-1. Based on rock cores collected by the United States Geological Survey (USGS), most or all of the uppermost formation of the Lockport Group, the Guelph Formation, is missing in the vicinity of the NFARS sites. However, it is present in Wheatfield east of the base (Brett et al 1995) and up to 3 feet of what is believed to be Guelph formation has been observed at Site 3 during previous trenching activities for other projects (E & E 1999c). Underlying the Guelph Formation is the Eramosa Formation, which generally consists of at least 50 feet of medium- to massive-bedded, dark brownish gray, biostromal, bituminous, dolostone. This formation is further subdivided into six informal units that are characterized by coral-rich, vuggy, oolitic, and/or stromatolitic layers (Brett et al 1995). Vugs are often filled with secondary minerals including sphalerite (zinc sulfide), galena (lead sulfide), fluorite (calcium

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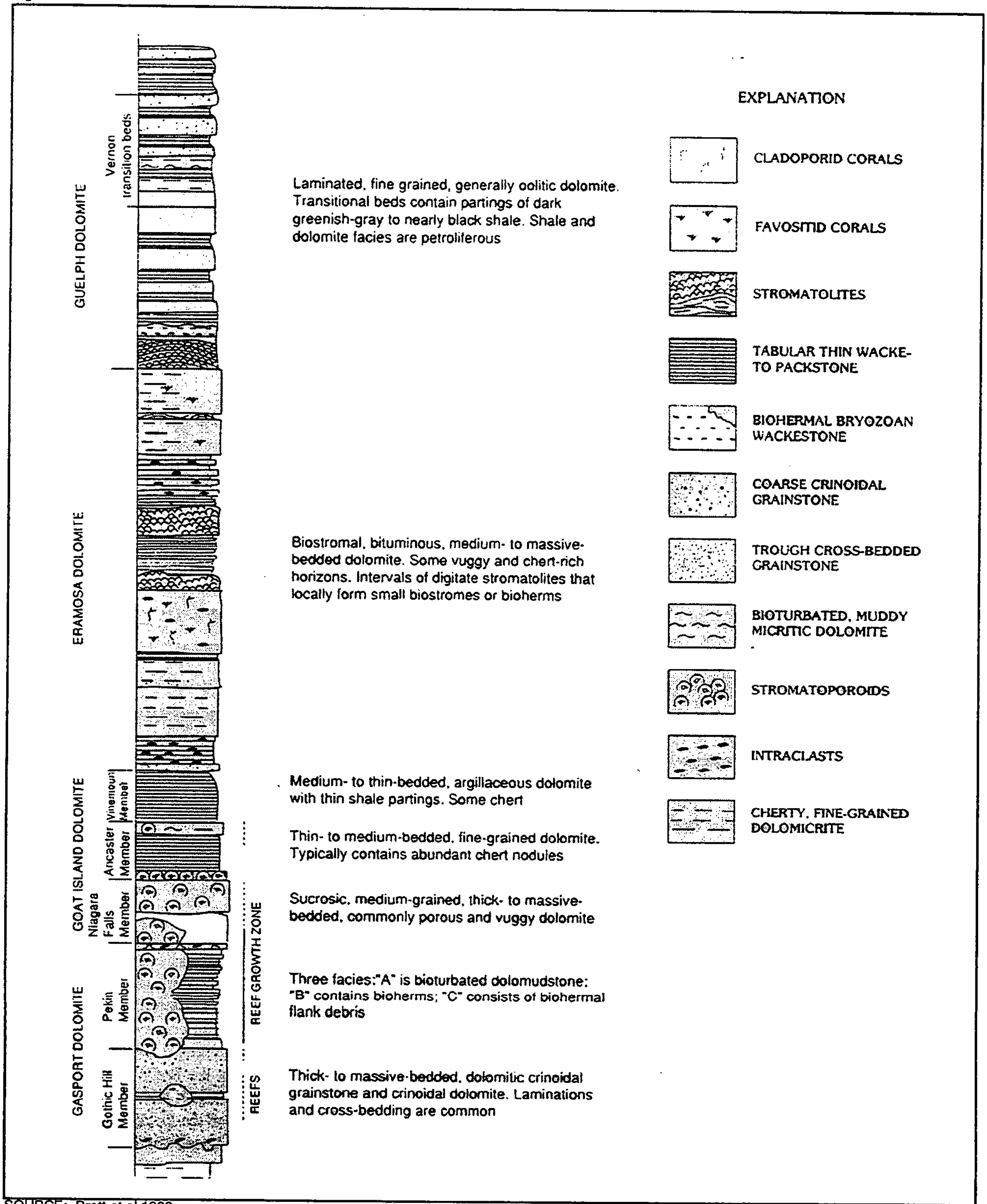
Fig4-1.CDR-6/16/99-GRA



SOURCE: Brett et al 1999.

Figure 4-1 TYPICAL STRATIGRAPHIC COLUMN OF THE LOCKPORT GROUP IN NIAGARA COUNTY NEW YORK

fluoride), gypsum (calcium sulfate), calcite (calcium carbonate), and dolomite (calcium magnesium carbonate).

4.2 Stratigraphy of the Niagara Falls ARS

The overburden present at NFARS consists (in descending order) of 3 to 18 feet of fluvial deposits, lacustrine deposits, and glacial till. These deposits are described in detail in other reports (E & E 1999a) and are not the focus of this report.

As discussed in Section 3, a detailed inspection of five rock cores from Sites 3 and 10 (MW3-8E, MW3-6D, MW3-1E, MW10-1F, and MW10-3E) was conducted. Based on the results of this inspection, detailed bedrock core logs were produced for each of these wells (see Figures 4-2 through 4-6, respectively). Each core showed alternating zones of relatively high, moderate, and low porosity, which was described primarily as a function of the presence of vugs and dissolution of biostromal zones (fossilized corals). Horizontal and minor vertical fracturing was observed in all cores. Most were open, water-bearing fractures. Some of the open fractures contained secondary mineralization of calcite, gypsum, and dolomite, and some were healed (i.e., completely filled with minerals). Many vugs contained the same secondary minerals plus sphalerite. Numerous stylolites (thin, generally black, irregularly shaped contacts formed during diagenesis [rock formation]) existed throughout all of the cores.

Examples of the stratigraphic features described above are shown in Photos 1 through 8 (see Appendix A).

4.3 Stratigraphy of the Bell Aerospace Textron Site

The overburden present at BAT consists of silty glacial clays overlying lacustrine sediments and basal till (Grasso and Smith 1993). It ranges in thickness from approximately 16 feet adjacent to the plant to about 30 feet, one mile to the south. These soils are similar to those at NFARS and have been determined to act as a semi-confining layer to the underlying bedrock strata (Grasso and Smith 1993). However, secondary permeability in the form of vertical discontinuities may locally provide a hydraulic connection similar to at NFARS.

Information obtained from detailed borehole core logging and hydraulic conductivity packer testing investigations conducted at the BAT site has been used to subdivide the underlying bedrock of the Guelph and Eramosa formations into four hydrostratigraphic zones.

These zones are considered the primary areas of concern with regard to groundwater quality beneath the site (Golder Associates 1991).

Zone 1, the uppermost bedrock aquifer, includes the top 10 to 20 feet of bedrock beneath the BAT site and has been classified by Golder Associates (1991) as part of the lower Guelph Formation. It is described as a fine-grained, thinly bedded, light brownish gray dolomite with numerous open bedding partings (bedding fractures). The lower 1 to 2 feet of this zone, referred to as the "A Marker Bed," is characterized as a dolomite bed with abundant intergranular gypsum. It contains numerous bedding plane fractures and is generally the most permeable section on the site (Golder Associates 1991). The A Marker Bed has been identified in nearly all of the boreholes on the BAT site and is considered to be both laterally contiguous as well as the primary horizontal pathway for contaminant migration at this site.

Zone 2 is composed of an unweathered, medium to thickly bedded, massive dolomite approximately 8 feet thick and is interpreted to be the upper member of the Eramosa Formation (Grasso and Smith 1993). This zone is considered to be an aquitard that restricts groundwater flow from the overlying Zone 1 aquifer to the underlying Zone 3 aquifer (Grasso and Smith 1993). Zone 3 is a notably porous and vuggy dolomite that varies in thickness from about 18 to 29 feet at the BAT site. This confined aquifer was determined to have a lower hydraulic conductivity than the Zone 1 aquifer (Grasso and Smith 1993). Zone 4 is a fine- to medium-grained dolomite with medium to very thick bedding. The hydraulic conductivity of the Zone 4 aquifer was determined to be less than that in Zone 3. Both Zone 3 and Zone 4 are part of the Eramosa Formation.

Horizontal groundwater flow in all hydrostratigraphic zones is primarily to the south and reflects regional groundwater flow toward the Niagara River (Grasso and Smith 1993). Vertical groundwater flow is generally downward from the overburden aquifer toward the Zone 1 bedrock aquifer, where it moves downward toward the A Marker Bed at the base of the zone. The A Marker Bed serves as the predominant zone of lateral groundwater flow beneath the site. Both upward and downward hydraulic gradients have been measured between the Zone 1 and Zone 3 aquifers as well as between the Zone 3 and Zone 4 aquifers (Grasso and Smith 1993).

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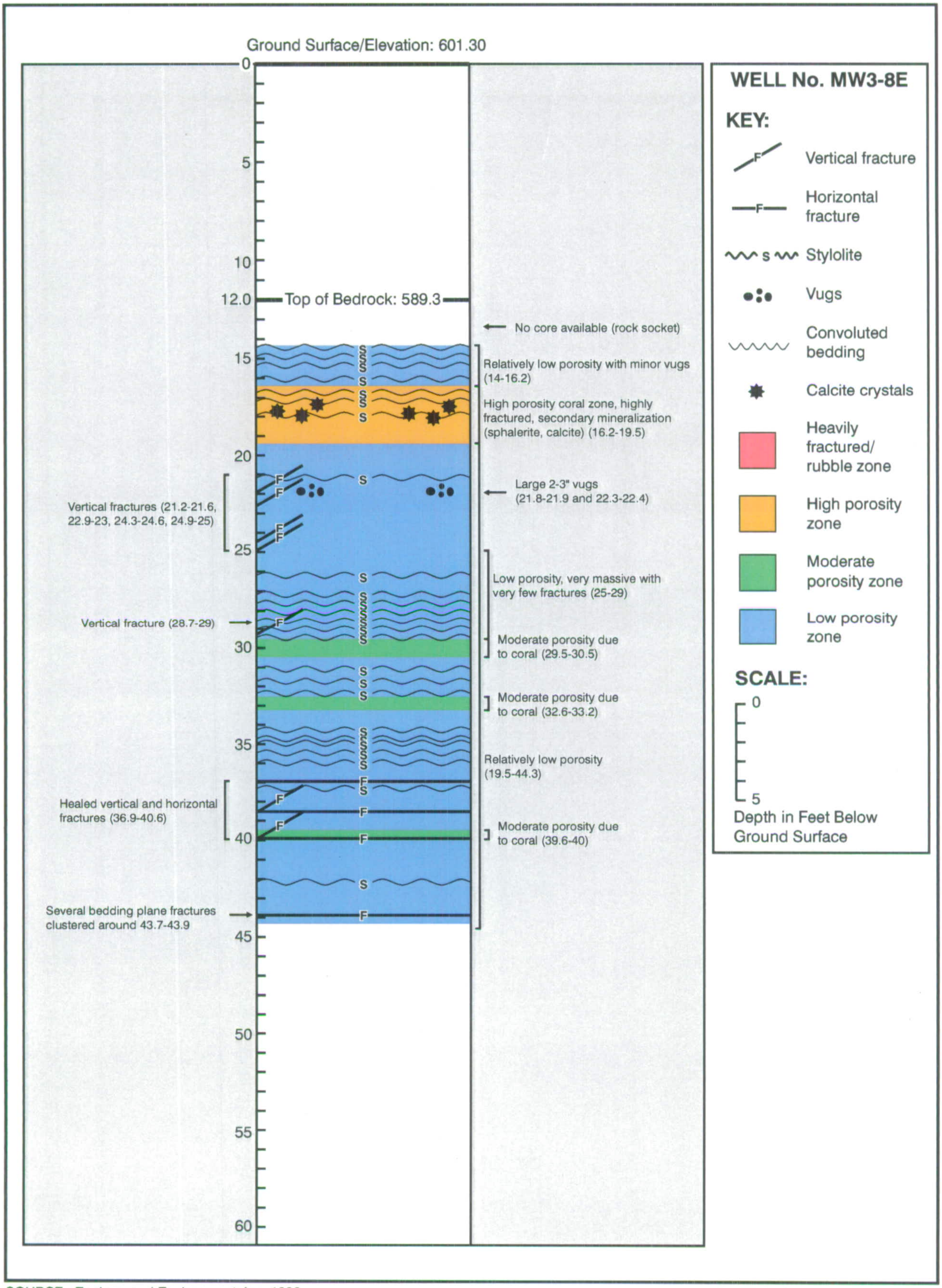

SOURCE: Ecology and Environment, Inc. 1999

Figure 4-2 BEDROCK CORE LOG OF MONITORING WELL MW3-8E NIAGARA FALLS AIR RESERVE STATION

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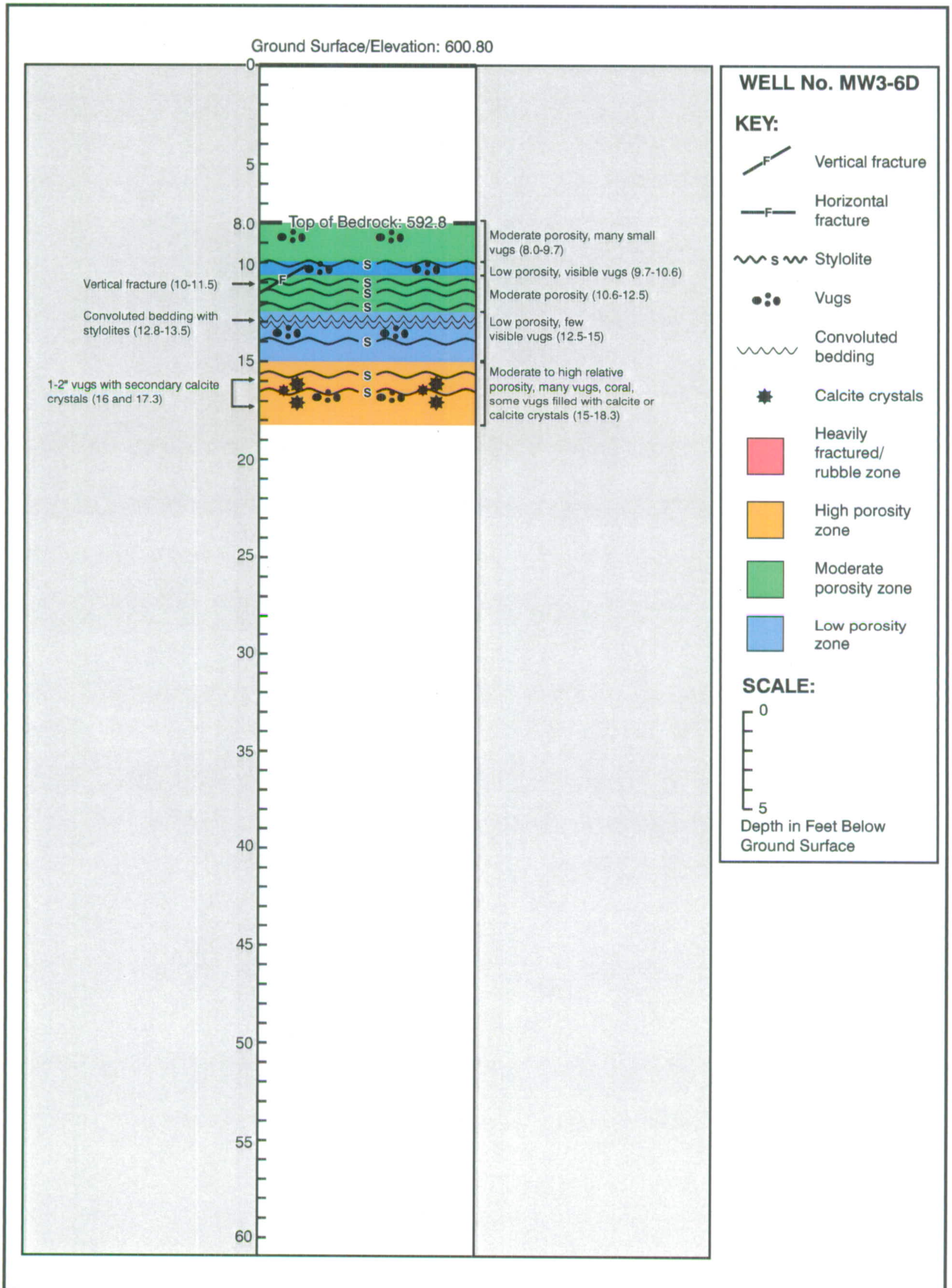

SOURCE: Ecology and Environment, Inc. 1999

Figure 4-3 BEDROCK CORE LOG OF MONITORING WELL MW3-6D NIAGARA FALLS AIR RESERVE STATION

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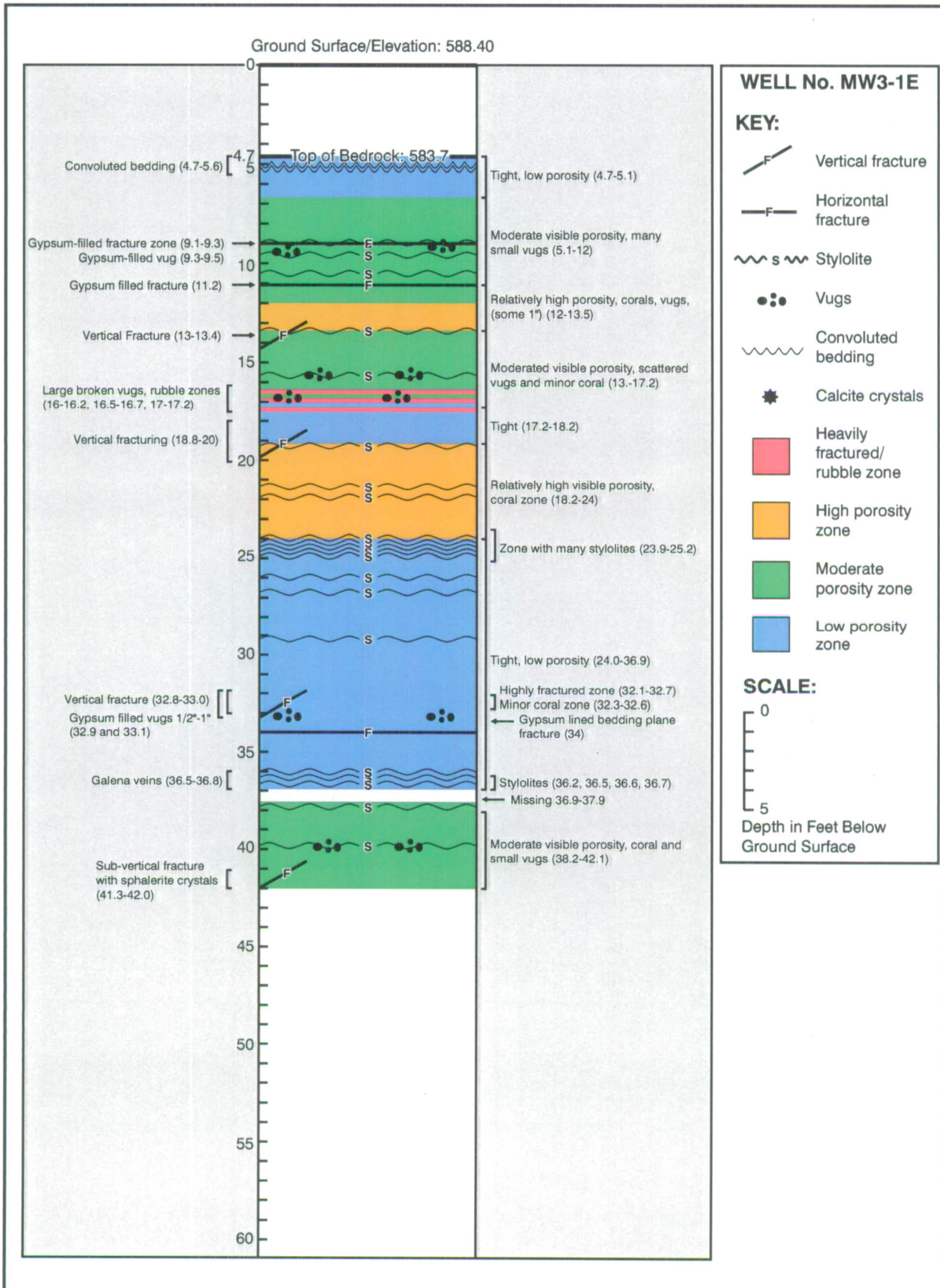

SOURCE: Ecology and Environment, Inc. 1999

Figure 4-4 BEDROCK CORE LOG OF MONITORING WELL MW3-1E NIAGARA FALLS AIR RESERVE STATION

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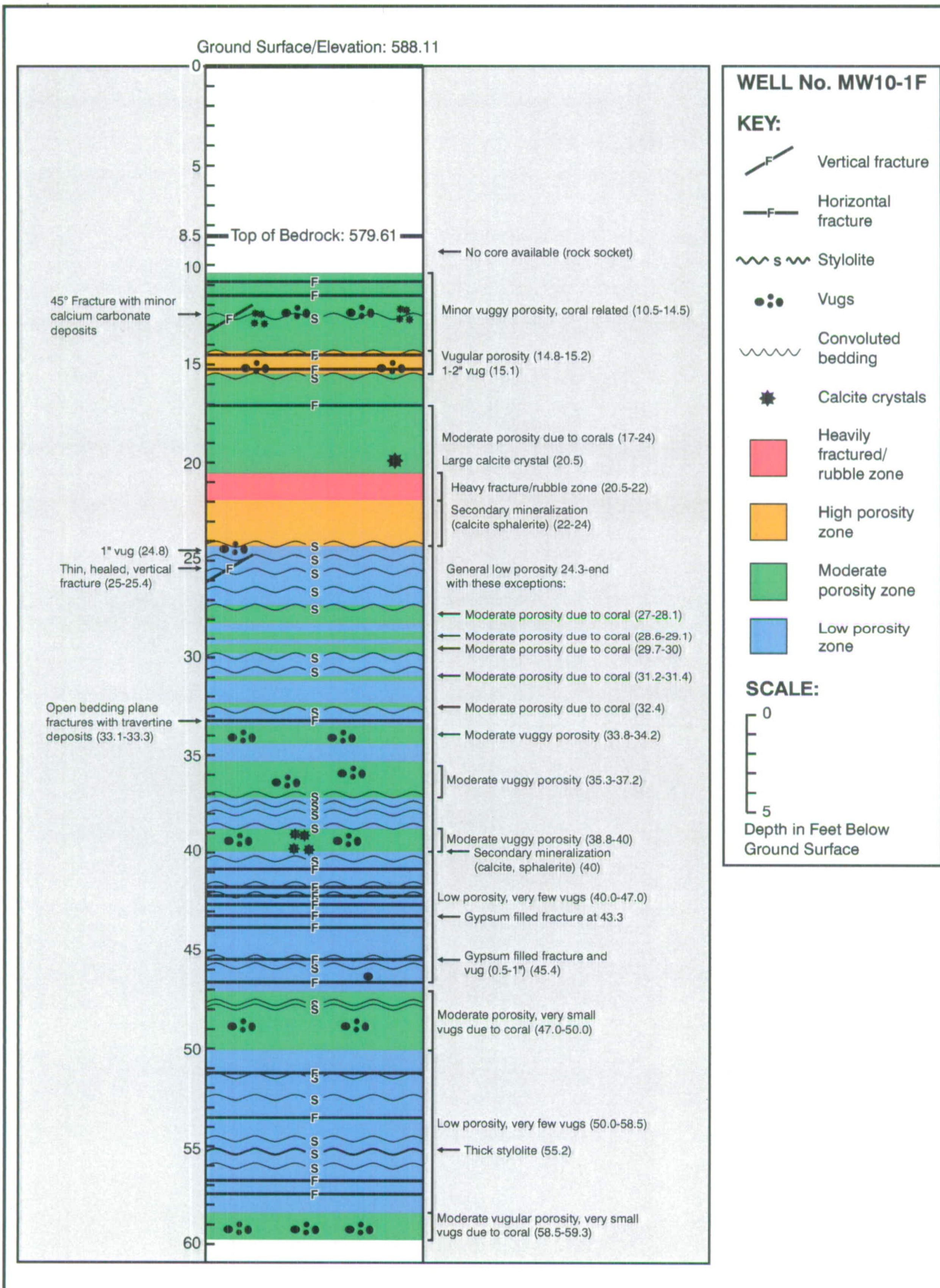

SOURCE: Ecology and Environment, Inc. 1999

Figure 4-5 BEDROCK CORE LOG OF MONITORING WELL MW10-1F NIAGARA FALLS AIR RESERVE STATION

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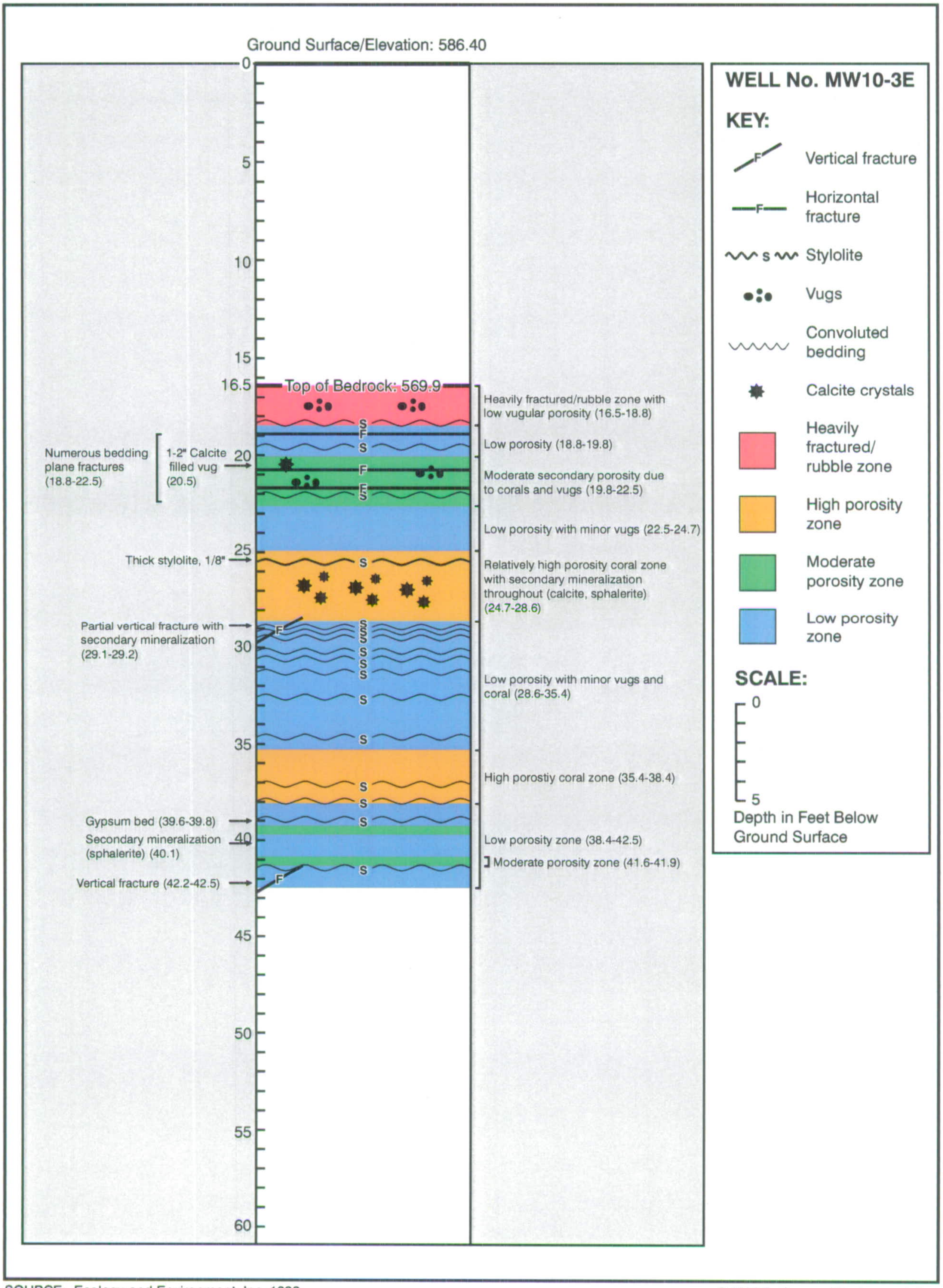

SOURCE: Ecology and Environment, Inc. 1999

Figure 4-6 BEDROCK CORE LOG OF MONITORING WELL MW10-3E NIAGARA FALLS AIR RESERVE STATION

4.4 Stratigraphy of the Carborundum Site

The overburden present at the Carborundum site consists of 17 feet of (in descending order) a mixed layer of silt and clay, stiff silty clay, and silty till. Bedrock was not drilled during investigative activities. Two water bearing zones were encountered in the overburden. One was confined to the silt till overlying the bedrock, and the other was perched water in the silty clay surrounding a disposal area. Groundwater flow on the bedrock-overburden interface was determined to be to the northeast (Advanced Environmental Systems Inc. et al 1981).

4.5 Stratigraphic Correlation With Surrounding Sites

A Marker Bed Projection

The A Marker Bed identified at the BAT site is considered the primary means of lateral contaminant transport beneath the site. In order to determine if compounds present at the NFARS site are contributing to contamination present at the BAT site, it was first necessary to determine if the A Marker Bed is present at NFARS. The strike, dip, and elevation of this bed at the BAT site was used to project the elevation of the A Marker Bed at NFARS. This data was acquired from Figure 5-3 (Interpreted Elevation Contours for the Base of A Marker Bed) of Golder Associates 1991. This information was compared to NFARS monitoring well elevation and stratigraphy data to estimate the location (if present) of the A Marker Bed at the NFARS site. An estimated projection of this bed is shown on Figure 4-7 which also depicts possible correlations between the NFARS well cores described above.

An average dip of approximately 34 feet per mile to the south was calculated for the A Marker Bed. This slightly exceeds but generally corresponds with the regional bedrock dip in the Niagara Falls region. A localized dip to the southeast is also represented on the Golder Associates map in the area of highest data point concentration adjacent to the site. However, the regional southward dip was determined to be the most representative of the subsurface conditions in the region, including the NFARS and BAT sites. A reference point was chosen at the BAT site (Well No. 86-24B) where the elevation of the base of the A Marker Bed is known (555.5 feet above mean seal level [AMSL]). Using the calculated dip, the elevation of the base of the A Marker Bed was projected from this reference point to several wells at NFARS Sites 3 and 10.

AMSL
above mean sea level

Comparing the projected elevation of the bottom of the A Marker Bed to top of bedrock elevations at several locations at NFARS revealed that the A Marker Bed is likely not a contiguous aquifer stretching between the BAT site and NFARS. In most wells examined at NFARS Sites 3 and 10, the base of the A Marker Bed was projected above the top of bedrock. Where projected to exist at Sites 3 and 10, the base of the A Marker Bed would be only a few feet below the top of bedrock and well within the range of error associated with the projection. Detailed study of cores from monitoring well MW3-6D, where the projection of the A Marker Bed did correspond to existing bedrock, revealed that this projection correlated with a vuggy zone of moderate porosity.

As mentioned above, the A Marker Bed is described as a bed of abundant intergranular gypsum and is commonly the most permeable zone encountered at the BAT site (Golder Associates 1991). Although relative porosities suggest a possible correlation between the A Marker Bed and the vuggy zone observed in MW3-6D, the variability of the descriptions does not corroborate such a correlation. A close examination of the upper bedrock in several wells at Sites 3 and 10 revealed no distinct zone that may be consistently correlated with the A Marker Bed. In addition, the 8-foot-thick aquitard present at the BAT site does not appear to be present at the NFARS site.

All of the cores examined from wells at NFARS showed alternating zones of relatively high, moderate and low porosity, which was a function of the presence of fractures, vugs, and dissolution of fossilized corals. Minor horizontal and vertical fracturing was observed in all the cores, many of which contained secondary mineralization of calcite, gypsum, and sphalerite. The vugs observed contained these same minerals. Numerous stylolites existed throughout all of the cores.

Figure 4-7 depicts two distinct units that possibly correlate between cores. The first was a relatively high porosity zone that ranged in thickness from 3 to 5 feet. This was seen in all of the cores at an approximate depth that would suggest they may be the same unit. The second was a characteristic clustering of stylolites associated with a low porosity zone immediately underlying the relatively high porosity zone, which was observed in four of the five cores.

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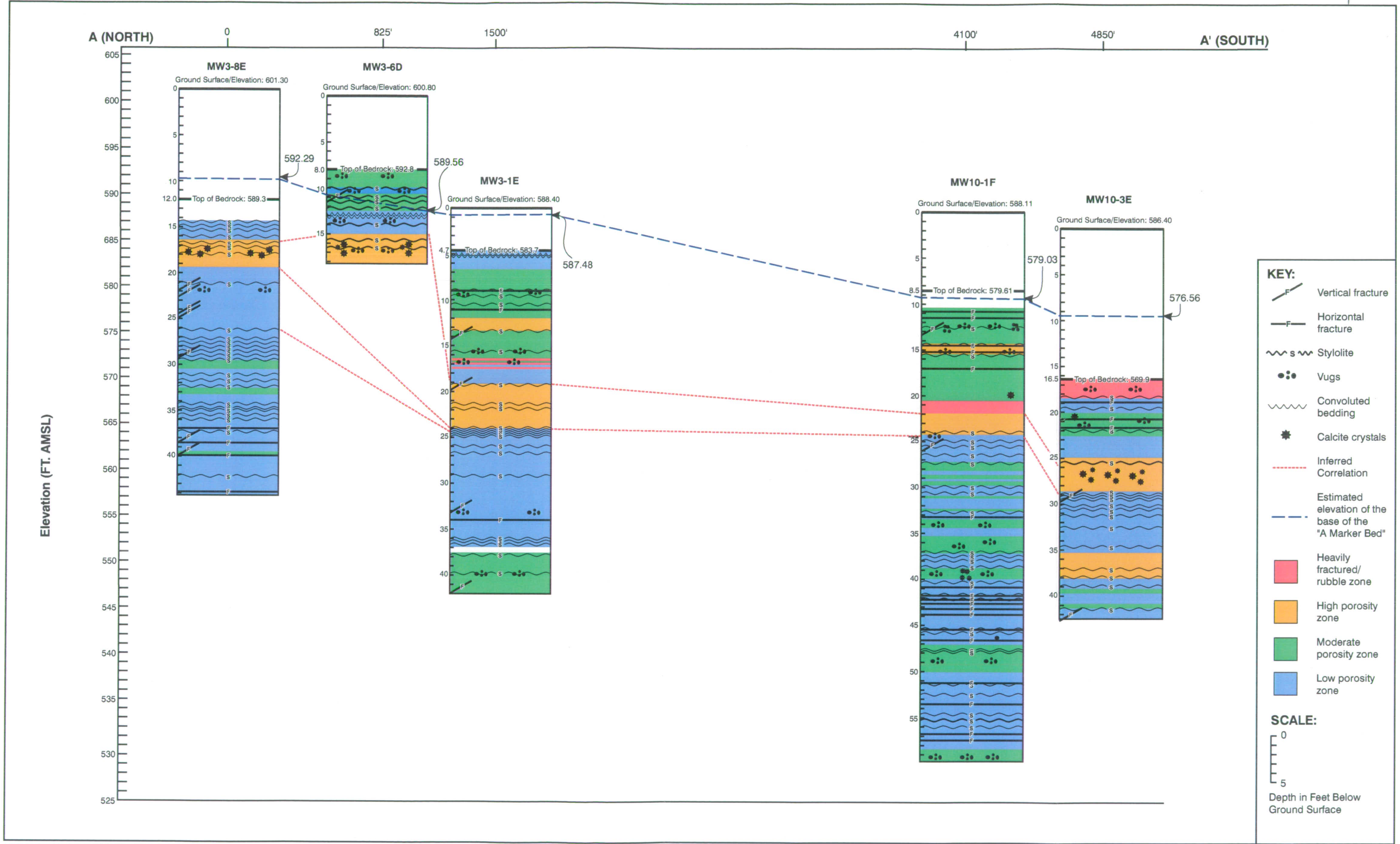
Fig4-7.CDR-6/14/99-GRA



SOURCE: Ecology and Environment, Inc. 1999.

Figure 4-7 COMPARISON OF CORE LOGS NIAGARA FALLS AIR RESERVE STATION

5 Conclusions

Lateral migration of shallow bedrock contamination southward from NFARS to the BAT plant is very unlikely for the following reasons:

- The A Marker Bed that controls the majority of groundwater contaminant transport at the BAT site appears to be laterally discontinuous, and does not appear to be present at NFARS;
- Wells at the southern ends of Sites 3 and 10 that are downgradient of areas exhibiting some of the highest groundwater contamination levels at NFARS have been consistently free of volatile organic contamination;
- Cayuga Creek acts as a hydraulic boundary for the overburden and shallow bedrock water-bearing zones between NFARS and the Carborundum and BAT sites;
- No volatile organic contamination has been identified in the monitoring wells at the Carborundum site, which is located between NFARS and BAT; and
- Maps prepared by Golder Associates show a well-defined northern boundary of the contaminant plume at the BAT site.

6 References

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A Photographs

The rock cores shown in the following photos were examined in detail for this report. The top of the cores, in most cases representing the top of bedrock, are located in the upper left corner of each core box. The depth at which each section of core was taken increases from left to right, such that the bottom of cores are located in the lower right corner of each box. All depths labeled in the photos are in feet below ground surface (BGS).

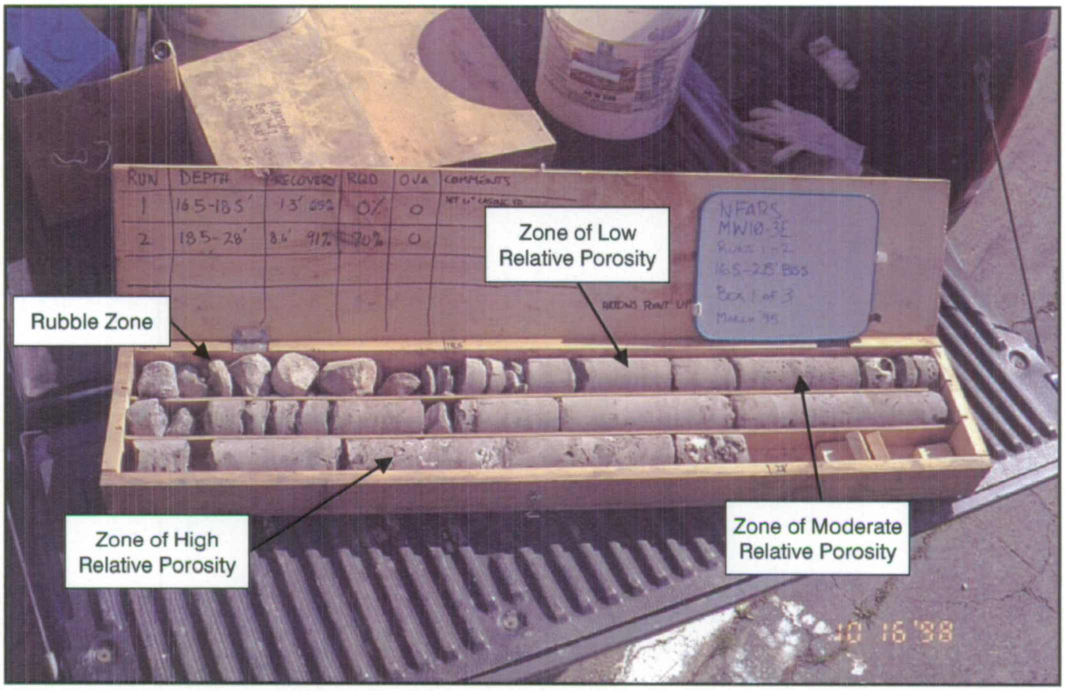

Photo 1 **NFARS Rock Core MW10-3E**

Comparison of zones of different relative porosities.

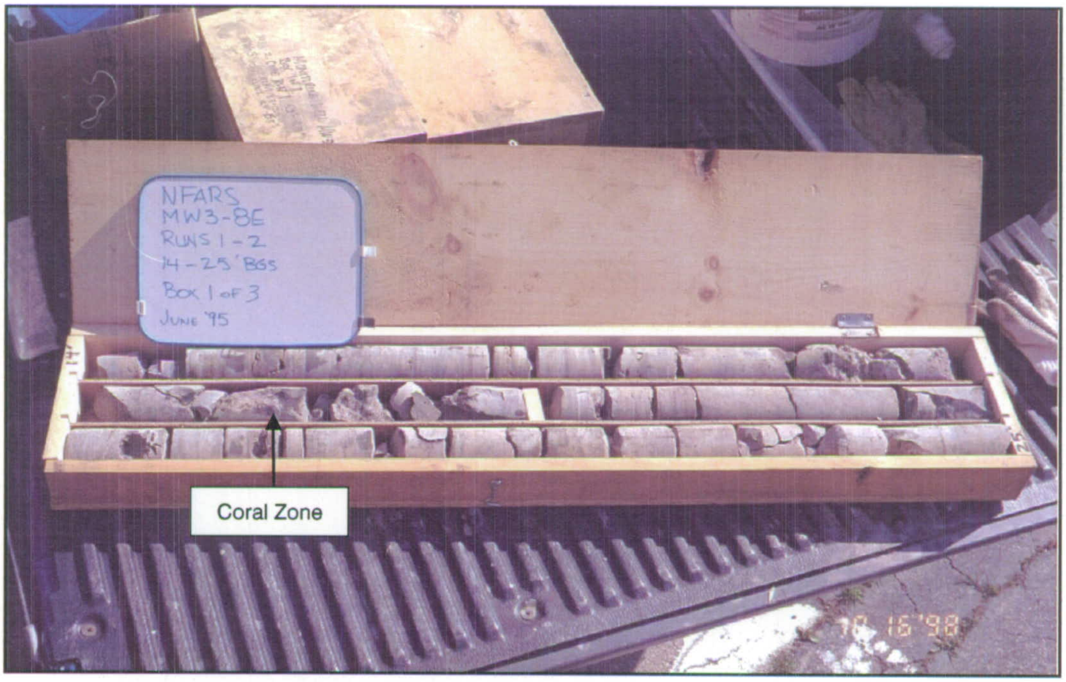

Photo 2 **NFARS Rock Core MW3-8E**

Comparison of zones of different relative porosity including coral biostrome and vugs.

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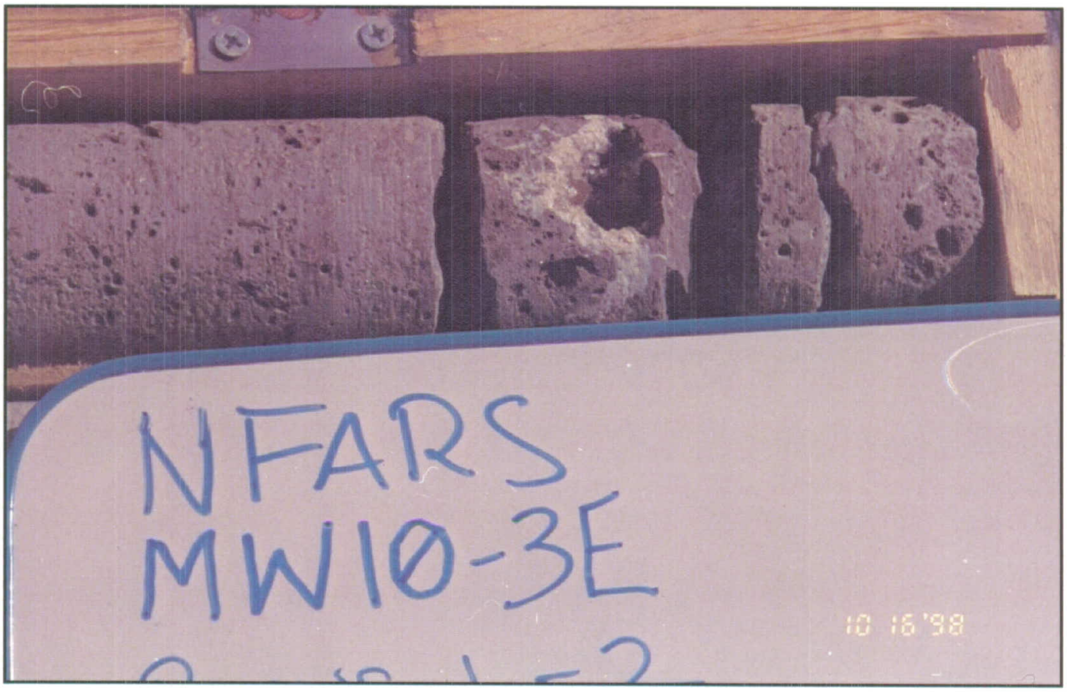

Photo 3 **NFARS Rock Core MW10-3E**

Large mineral-filled vug below zone of moderate porosity. Moderate relative porosity from dissolution of coral biostrome zone.

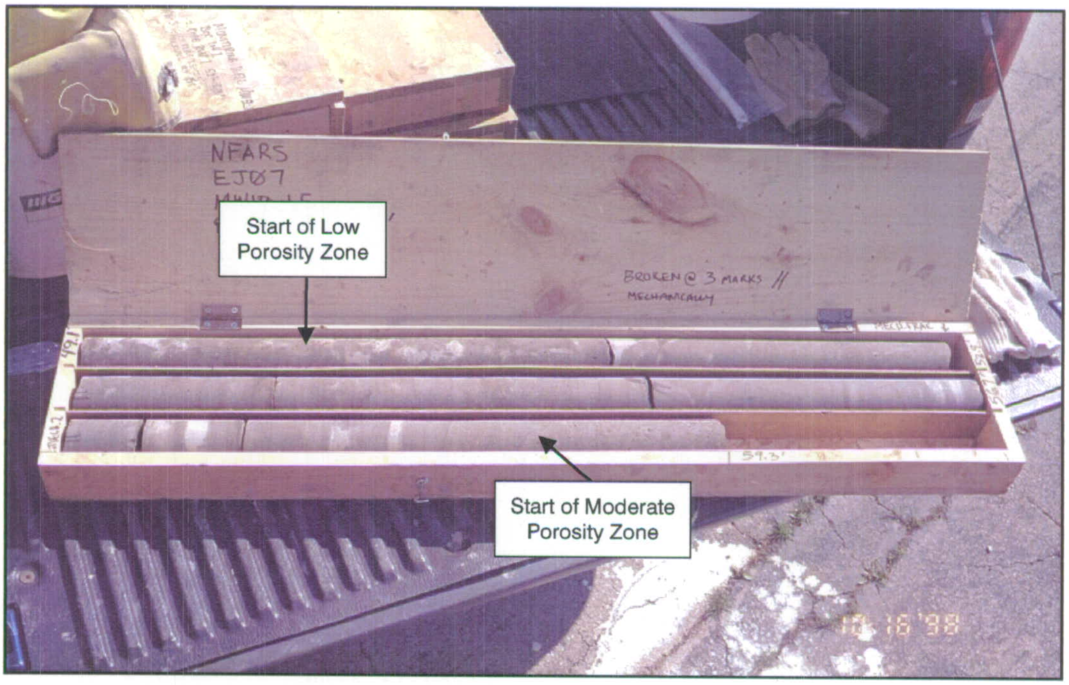

Photo 4 **NFARS Rock Core MW10-1F**

Example of low relative porosity in deep bedrock zone.

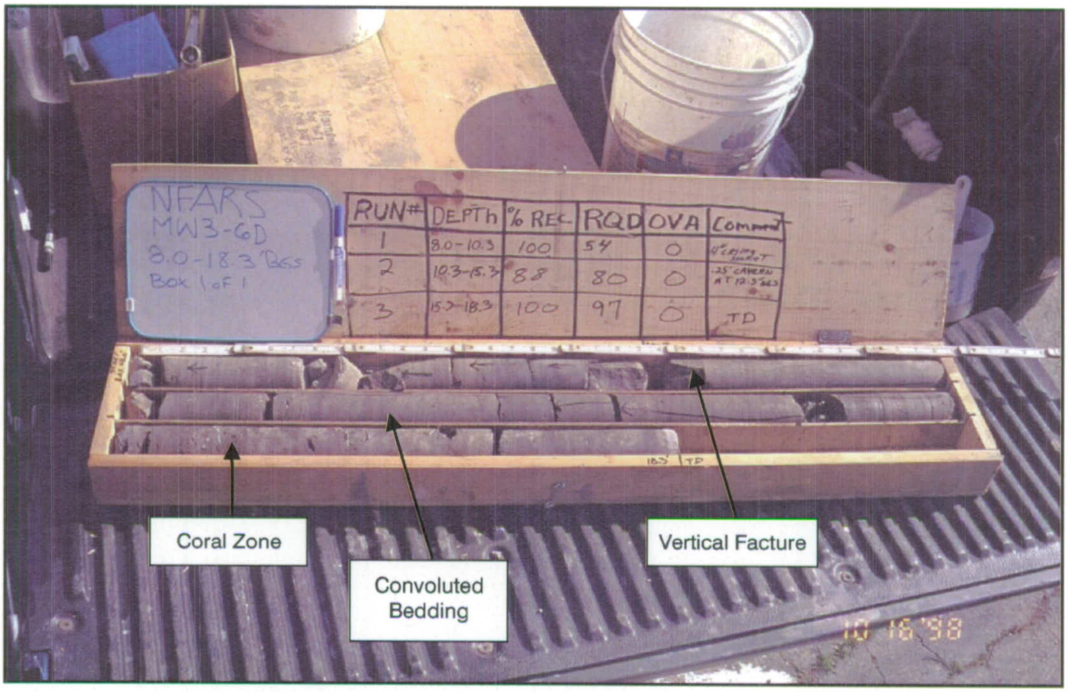

Photo 5 **NFARS Rock Core MW3-6D**

Example of fracturing, convoluted bedding, and coral biostrome zone.

Photo 6 **NFARS Rock Core MW3-6D**

Close-up of vertical fracture.

Photo 7 **NFARS Rock Core MW3-1E**

Example of gypsum-filled fracture.

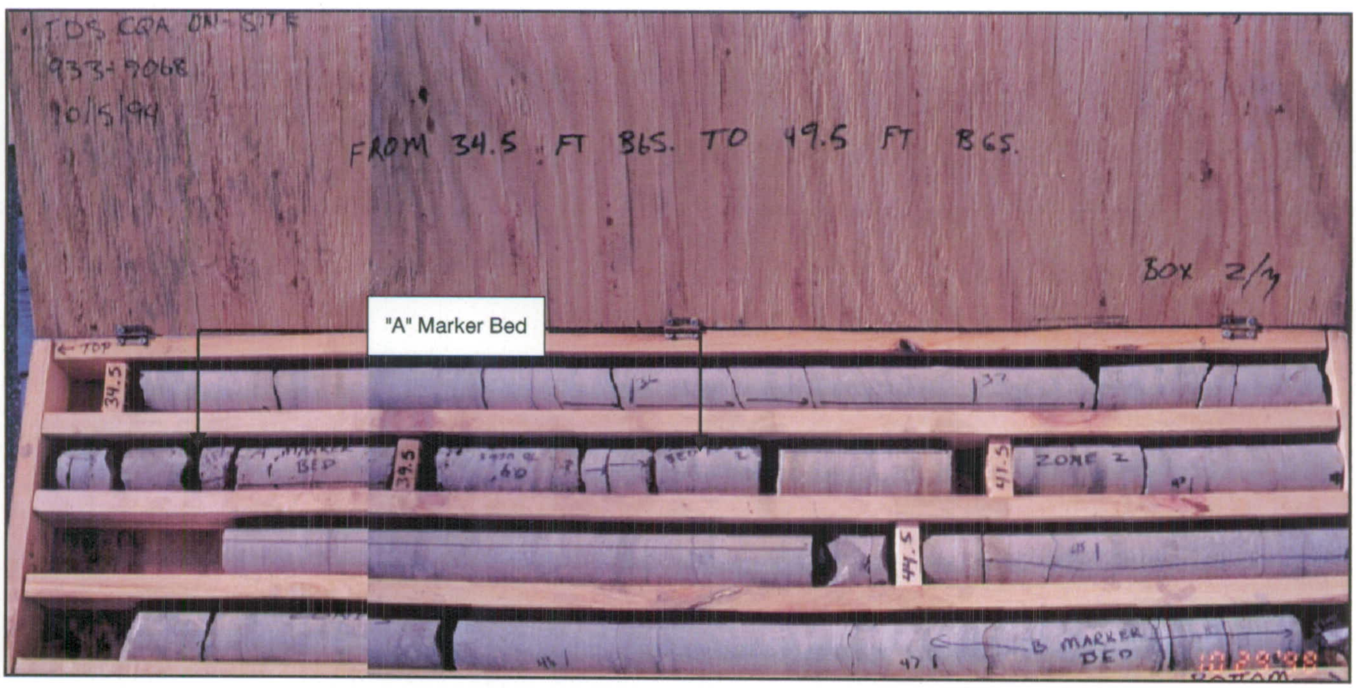

Photo 8 **BAT Site Rock Core 94-02(1)**

Example of BAT stratigraphy including zones 1 and 2 and marker beds A and B.