NATURAL ANALOGS

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Natural Analogs Research Project.

second field book with entries by William M. Murphy

Contents

Santorini 1994

Murphy and Green arrive 8/23/94.

WMM is William M. Murphy

4 WMM 8/24/94

8/24/94 Reconnaissance tour was taken prior to arrival of Christos Doumas looking for outcrops of Cape Riva for testing coring and augering devices, and looking at the contrast between present/recent alluvial deposits and the late steye flood deposits of the Minoan eruption.

In the major ravine east of the archaeological site there is recently deposited alluvium. It was compared to flood deposits. A similar comparison was made by Murphy in the 1993 field effort. Major deposits observed at the archaeological site are much more extensive, coarser, thicker, and heterogeneous. Conclusions of 1993 were confirmed by Murphy and Green.

The area south and west of the town of Akrotiri was examined for pre-Minoan exposures especially of rocks like the Cape Riva below Δ3. The best candidate observed was the ridge south of the town and north of the prominent red flow unit that supplies sediment to Red Beach.

WMM WM 8/24/94

8/24/94

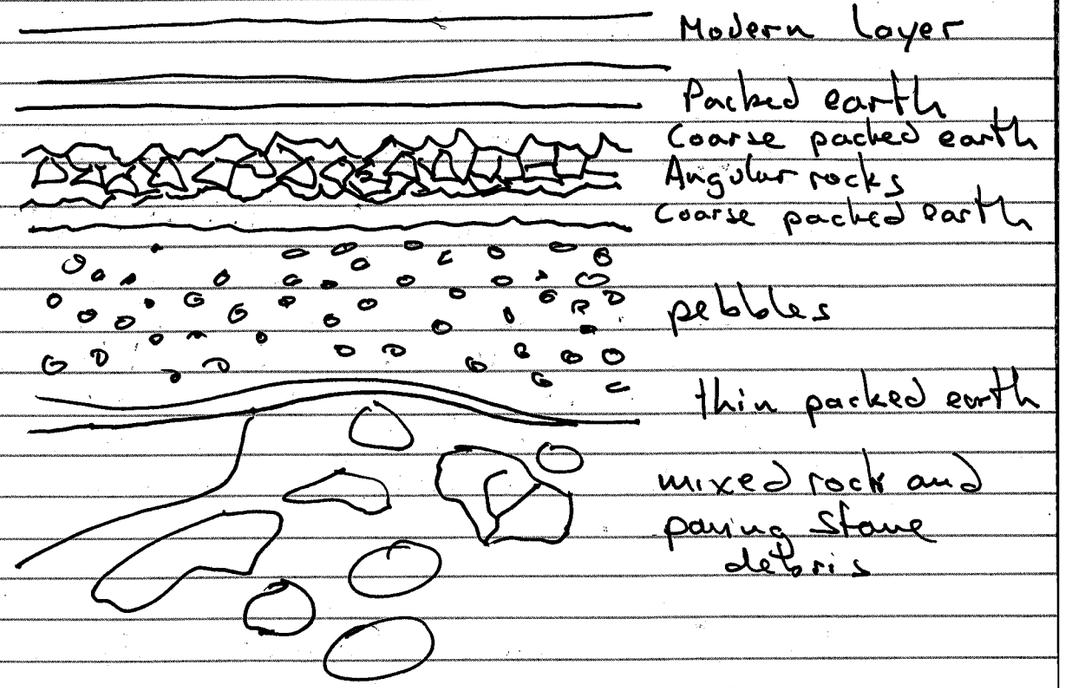
Doumas greeted Murphy and Green in the site near ΔJ where current excavations are occurring.

He described work being conducted under the direction of Peggy in the area outside buildings, an area referred to as "the square." The geometry, structure, and topography of this area is complicated. The surface of the Minoan square is nearly two meters vertically above the floor of ΔJ and at a minimum only 2 to 3 meters north. Excavations are occurring below the surface of the square to examine earlier stages of occupation of the site. A sketch of the stratigraphy is given on page three facing west.

At a point just above the Cape Riva bedrock, but considerably below the surface of the square (and the surface horizon at the time of eruption) a chisel and two clasps were found made of bronze. These had been buried considerably longer than the bronzes buried by the eruption, perhaps 1000 yr according to Doumas.

See continued discussion on page 22.

WWM 8/27/94
10/24/94



The modern layer was placed to facilitate tourist and worker traffic. The upper packed earth is the Minoan surface at the eruption time. The coarse packed earth surrounds and forms the matrix of the Angular rocks. Materials above the pebbles have an obvious appearance of human engineering. The pebbles look like a coarse gravel deposit, i.e. natural, although Doumas suggests it's human made. It could be fill collected from an alluvial deposit or the beach. Material below it is clearly of Minoan origin + is fill.

WWM 8/27/94
10/25/94

Notes taken 8/24/94

WWM 8/27/94

10/24/94

8/25/94 Testing of coring and augering equipment.

Adjacent to hydrology test hole outside Δ3 ⊗ from fieldwork in 1993 a hole was successively augered and cored. ⊗ near the NE corner

Samples were collected from successive depths as listed below. All are Cape Riva tuff with a slight purple color. The coring device is mainly a pulverizing device - so most rock fragments are small to pulverited.

Depth*	Sample number	Extraction
34-36 cm	SAN94-001	in core barrel
38-39 cm	SAN94-002	"
39-41 cm	SAN94-003	"
43-48 cm	SAN94-004	by hand
50-58 cm	SAN94-005	"
60-66 cm	SAN94-006	in barrel
66-70 cm	SAN94-007	in barrel with catcher

*relative to bedrock surface

8/25/94

Photographs for this trip are taken with Murphy's camera and numbered successively with the prefix SAN94-P

P SAN94-P1 is of Green preparing to core at the 1/2 meter depth intival in the hole exterior to the NE corner of Δ3.

Samples SAN94-001, 002, and 003 were collected from the coring device. Samples SAN94-004, and 005 were collected by hand from the bottom of the hole because they didn't come up w/ the core. Nevertheless, the material is almost entirely from the depth indicated - little or no sidewall material dropped because the hole is quite clean - over augered - and material was cleaner from around the top. SAN94-006 was collected from the barrel which it filled to about 10 cm length although the hole deepened by only ~5 cm.

8/25/94

Samples SAN94-001 to SAN94-007 were taken close enough to the infiltrometer borehole of 1993 fieldwork that water from that test could/would have affected it.

8/25/94

Our second hole is outside Δ near the southeast corner.

Depth (is from bedrock surface)

	Sample #	Recovery
0-5cm	SAN94-008	in barrel
13-18cm	SAN94-009	"
19-28cm	SAN94-010	"
28-35cm	SAN94-011	"
35-43	SAN94-012	"
44-49	SAN94-013	"
49-52	SAN94-014	"
53-57	SAN94-015	"
58-62	SAN94-016	"

Following action described on page 8.

WWH 8/25/94

P SAN94-P2 is a photo of Green commencing core digging at the second hole.

A gypsum plug was inserted at the base of the first hole and packed in the powdered rock removed from the hole but not sampled. It is called gypsum block 94A or GB94A.

Gypsum block data

Site	Date	Time	Reading	Initial	Comment
GB94A	8/25	12:40PM	0	WWH	see above
GB94B	8/25	2:10 PM	0	WWH	see pg. 8 red
GB94C	8/25	2:10 PM	0	WWH	see pg. 8 green
GB94B	8/26	9:00 AM	7	WWH	
GB94C	8/26	9:00 AM	0	WWH	
GB94A	8/26	9:00 AM	2	WWH	

See following information in Ron Green's notebook

WWH 8/29/94

WWH 8/26/94

GB94B was placed at a depth of 60 to 62 cm in the cored hole outside the Southeast corner of △3 it is labelled on its wire near the surface with one strand of red tape.

GB94C was placed in the same hole as GB94B but at a depth of 30 cm. It was labelled with green tape. The hole with the GB's noted above was backfilled with powdered rock from the hole.

Measurements at the two gypsum block sites under the excavation shelter are 23 and 26 respectively in the northern and southern site. These blocks were established in 1993, and at the end of the field season the readings were near 60. This year has been reported an exceptionally dry year and the difference may reflect year to year variations in moisture.

The gypsum block in the ravine north of the excavation read 24, also much below final readings in 1993.

WHH 8/25/94

A discussion with Doumas led to an inspection of the saw taken from △8A. The tip of this artifact was most likely the object observed in 1993 in △8A. It was excavated earlier this summer in July. Unfortunately we were not informed in advance as we had requested. The artifact looks like a modern cross-cut saw blade with carbonized remnants of a handle with wooden brackets for attachment. The archaeologists carefully scraped off most of the corrosion products and painted it with a sort of lacquer (sp?). Annie who provided us with bits of corrosion products and bronze in 1993, gave us a vial of green to gray-brown corrosion products and adjacent ash cleaned from the saw. The vial is labelled △8a saw 7317 1994. 1994 is the year and 7317 is the artifact number of the archaeologists for the saw. This material is identified as SAN94-050. WHH 8/31/94

WHH 8/25/94

8/26/94

A warm humid morning. There will be much sweat today.

The third core will be in the center of hole VI from 1993 field work.

Depth from bedrock surface interpolated from the east and west sides of hole III

Depth (cm)	Sample	Recovery
13-18	SAN94-17	in barrel
19-22.5	SAN94-18	by hand large pieces are most representative
25-28	SAN94-19	barrel
32-36	SAN94-20	barrel
37-39	SAN94-21	by hand w/ slight contamination from sidewall.
39-42	SAN94-22	sample collected from hole by hand after over augering. This is a piece of core that was not recovered w/ 94-21 from below it
43-48	SAN94-23	by hand w/ slight contamination ~~core~~-site fragments are least

WWW 8/26/94

Fourth hole

Cored in hole III from 1993 - the hole in the SE corner.

Depth from bedrock surface interpolated N to S.

	Sample	Recovery
11-18.5	SAN94-24	barrel
11-13	SAN94-25	A single piece taken from the top of the core barrel (above SAN94-24)
20-26.5	SAN94-26	barrel + several chuncks taken by hand
30.5-37	SAN94-27	95% Collected by hand and with a scooping auger (5%). This sample is relatively more contaminated w/ sidewall material (1% ?).
42-49	SAN94-28	~1/2 by hand + ~1/2 in barrel behind plastic catcher

P SAN94-P3 is of the over augered bore holes in 1993 holes III and VI

WWW 8/26/94

The fifth borehole is south of 1993 hole III.

Samples SAN94-29, -30, and -31 are packed earth, mixed packed earth and Cape Riva tuff and mostly Cape Riva tuff, respectively from this spot. The first SAN94-29 was taken from ~6 to 3 cm above the bedrock. SAN94-30 was taken from ~ 3 cm above to 1 cm below the bedrock; and SAN94-031 was taken from the top 6 cm of bedrock. Coring starts here.

Depth (cm)	Sample	Recovery technique
6-12	SAN94-032	by hand
13-22	SAN94-033	"
22-33	SAN94-034	hand and barrel
~~22-34~~		
25-30	SAN94-035	in core tube. Nearly intact section possibly good for hydro testing.
36-41	SAN94-036	Mostly in core = some by hand
46-51	SAN94-037	hand and in barrel

The fifth borehole is 40 cm from the fourth borehole and 43 cm from the third borehole to the south

8/26/94

P SAN94-P4 is of Green's infiltrometer site atop Xeste

P SAN94-P5 is the fifth borehole in relation to the third (in VI) and the fourth (in III) and to the east wall of Δ3.

The second borehole is 1.1 m south and 85 cm east of the fourth borehole (in III).

Borehole one (The first borehole) is close to 3 m north of the second bore hole and 90 cm east and 130 cm north of the center of hole I of the 1993 season.

The bedrock level of boreholes second, third, fourth, and fifth is close within a few centimeters. The first borehole bedrock level is approximately 40 cm higher in elevation.

8/26/94

8/27/94 A reconnaissance survey of the stream valley just outside and adjacent to the fenced site to the east was conducted to find the base of the Minoan deposits and the underlying rock. The preminoan volcanics are exposed in small cliffs and a few horizontal surfaces near the stream. The rock is a lithic rich tuff, some cases having a red or slightly purple cast. It may or may not be equivalent to the Cape Riva below Δ3, but it appears to be the closest exposure of similar material. Green intends to test the moisture content in this rock to compare with gypsum block measurements in the preminoan volcanics under the site roof. Doumas should be advised and give consent, but this being Saturday morning no archaeologists are at work at the site and Doumas is away.

See continuation discussion on page 21.

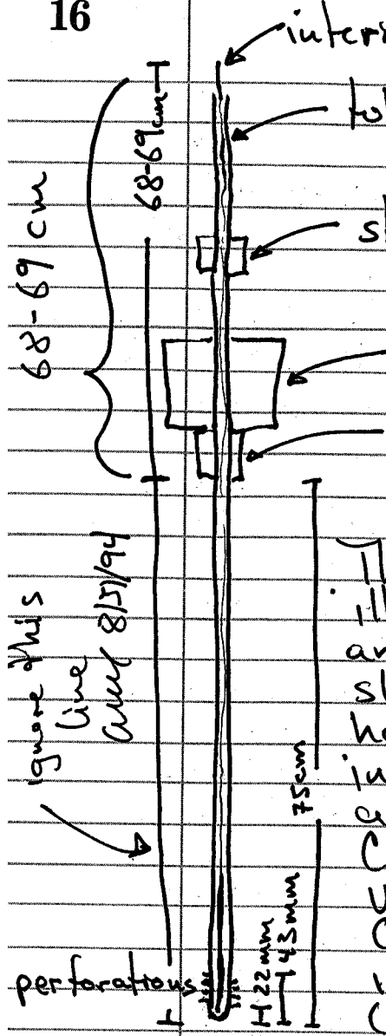
WWM 8/27/94

WWM 8/27/94

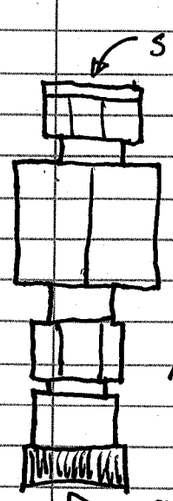
Gas sampling.

From the laboratory area a dirt road lead to the northeast and crosses the small stream channel where moisture content data have been taken (1993). On the north side of this road, inside the site fence, is an area of natural-appearing topography and vegitation. The vegitation consists of grasses and sage and a variety of small annual flowering plants which are presently mostly brown and dry. A fair number of grasses and flowers are still green. Some dry grasses are up to a meter tall, but most plants are 30 cm or less tall. The rock in the dirt road cut consists of a lithic rich Minoan ash with large lithic clasts of dark color, many are 5-20 (-30) cm in diameter in white fine ash matrix. This overlies a rock of similar ash but few xenoliths. A little more than 1 meter of this ash is exposed in the road cut. The soil is very thin to negligible in thickness. The first gas sampling site is in this area about 10 meters from the road.

WWM 8/27/94



The gas sampling device is illustrated schematically. It is an iron/steel tube with a sliding hammer and two hammer stops. A wire is inserted in the tube. This apparatus is also used by Chuck Connor in the CNWRA volcanology field research. Chuck reported that the interior volume of the tube (minus the wire volume) is approximately 10 cm^3.



↑ brass fixture with a gasket at one end and a plastic septum at the other fits on the end of the tube and seals to it by friction.

~actual size.

8/27/94

Gas is drawn out of the tube and fixture with a syringe inserted in the fixture septum.

Gas is placed in a glass tube with a septum top using the syringe. Available tubes are ~20 cm^3 in volume and not evacuated. They will be partially evacuated with the syringe the flushed with the gas sampled. prior to collecting a sample. After taking the sample the septum and bottle top are sealed with silicone sealant.

8/27/94

GAS SAMPLES

number	vial evacuations	flushes tube	flushes vial
SAN94GAS-001	4 x 20 cm^3	n.a.	4 x 20 cm^3
SAN94GAS-002	4	4	4
SAN94GAS-003	4	4	~4
SAN94GAS-004	3	1 additional	3
SAN94GAS-005	4	2 additional	4

WM 8/29/94

initial	date/time	site/comments
WM	8/27/94 10:50 AM	air at 1 meter above ground at site described on pg. 15.
WM	8/27/94 11:07	site described on pg. 15. Tube inserted 50 cm into ground until it hit something hard like a xenolith.
WM	8/27/94 11:23	~2 m from previous site under a small cluster of sparse sage plants with the tube inserted 75 cm (maximum depth).
WM	8/27/94 11:32 AM	same as for SAN94GAS-003 without moving the tube. Flushing the vial was probably more efficient than for the previous sample — reevacuation after flushing can cause a pressue below atmospheric in the vial and air leaks back in for an instant when the hypodermic needle is removed from the vial. The suction pressure was minimized this time.
WM	8/29/94 7:18 AM	Same as for two previous samples. Tube remained in place two days. Early morning sample.

suction heard was mainly (entirely) due to air reentering the syringe WM 8/31/94

WM 8/29/94

8/29/94 The sixth hole

Sample SAN94-43 is packed earth material taken from between holes IV and V from 1993 field work. The bedrock level reference for the sixth borehole is the level at this point. The sixth hole is going in the center of hole IV from 1995.

Depth (cm)	Sample	Recovery technique
8-13	SAN94-044	~1/2 in core barrel ~1/2 by hand
13-17	SAN94-045	by hand
19-25	SAN94-046	~2/3 by hand ~1/3 in barrel.
26-34	SAN94-047	~ 4/5 by barrel; 1/5 by hand.
36-41	SAN94-048	~ 1/2 + 1/2
44-49	SAN94-049	1/4 by barrel; 3/4 by hand probably some contamination from sidewalls

WM 8/29/94

The pre-Minoan tuff cropping out in the ravine to the east of the Akrotiri site is weathered and has a brown-orange color. It contains many pumice and other lithic fragments which are crudely layered horizontally. Fragments are commonly 5 cm and up to 30 cm across. A somewhat lower horizon ~ 1 meter below the Minoan surface has a more purple cast and more closely resembles the pre Minoan tuff in Δ3. It is better exposed on the west wall of the ravine, just west of the site fence. Green is boring a hole in this material where it crops out adjacent to the stream bed.

A sample of the weathered lithic rich tuff is SAN94-038

A sample of the underlying material from the west wall of the ravine is SAN94-039. It is also lithic rich but it is less weathered so the lithics don't stand out as obviously as in the overlying material. It has a red-brown to purple cast on freshly broken surfaces.

P ~~Photo~~ WM 8/29/94 Sample SAN94-039 consists of several large pieces in two (initially) sample bags. WM 9/1/94

WM 8/29/94

Dr. Peggy (Panayiota) Sotirakopoulou

Dr. Panayiota (Peggy) Sotirakopoulou supervised the excavation of the two bronze clasps and the bronze chisel underneath the square. According to here notes and drawings the items were located 15 to 19 cm above the bedrock surface in brown earth and pebbles. Stratigraphically this appears to be at the base of the "mixed rock and pumice stone debris" horizon described on page 3. It is also near the axis of the modern torrent that passes (passed) east of Δ3.

P Three photos SAN94-P6, -P7, and -P8 are views of the spot. A 3/4" cold chisel is placed for scale with its tip on the bedrock below the point where the artifacts were found. SAN94-P8 shows the site in relation to Δ3 which is in the background of the photo.

SAN94-040 is material chiseled from a spot ~ 5 cm x 5 cm square and 3 to 4 cm deep at the point below the artifact location.

SAN94-041 is material taken on deepening the 5x5 cm hole to 7 cm depth. It included one lithic fragment which may be regarded separately from the enclosing tuff.

WWM 8/29/94

P Photo SAN94-P9 is of the hole from which samples 040 and 041 were taken with a 10 cm scale.

Sample SAN94-042 is a flake of rock ~ 10 cm x 20 cm taken from the east wall of the cellar west of the Δ3 artifact site. The matrix is gray ash. Brown pumice fragments are ~30% of the rock which contains other lithic fragments and feldspar(?) phenocrysts

Pre Minoan rocks in the ravine to the east (e.g. SAN94-039) have a similar texture but are red as opposed to gray in color.

P Photo SAN94-P9A is of SAN94-042 with a pen for scale the pen points in the original vertical direction of the rock.

P Photo SAN94-P10 is a closer view of the same rock.

SAN94-P10 was discarded being badly out of focus. WWM 12/8/94

Photographs SAN94-P1 to P10 were taken with print film.

WWM 8/29/94

Floorstones that were piled in the southeast corner of Δ3 were moved aside exposing a hollow area mostly filled with packed earth and perhaps the mud-like mortar used in wall construction. It is mostly unconsolidated and heterogeneous. I suspect it is a dump of material by archaeologists and likely not in place. Packed earth elsewhere in Δ3 is friable but consolidated. The dump nature was confirmed on finding a cigarette butt, a wine cork and 2 rusted iron hooks ~ 10 cm long and 4 mm in diameter.

Removal of ~ 25 cm³ of the dump material revealed an irregular surface in part excavated (Minoan?) and apparently containing rounded rocks of the type seen in the pre-Minoan at the square.

P Photo SAN94-P11 shows the SE corner at this stage of excavation; the fifth borehole is in the picture and a spade points toward one of the rounded rocks of the Minoan's.

P Photo SAN94-P12 shows the sixth borehole in relation to 1993 holes

WWM 8/29/94

8/30/94 A survey was conducted of the volcanic stratigraphy looking for favorable sites for hydrologic measurements and developing a notion for the kinds of materials that may have overlain the bronzes in Δ3.

P Photos SAN94-P13 and SAN94-P14 are views from approximately the same spot looking downstream and upstream respectively along the trace of the "torrent" which also is generally parallel to a swale eroded by a more explosive stage of the Minoan volcanism.

Based on the height of the north and south walls of Δ3 which are approximately the same along a line passing along the western edge of the artifact (bronze) locations in Δ3, there was a minimum of 1.75 m of material above the Cape Riva bedrock surface.

P Photo SAN94-P15 shows an overview of the valley to the east of the site where a gypsum block was placed in pre Minoan tuff by Green. That site is across the stream from a small cliff (where sample SAN94-039 was taken) and just downstream from the donkey yard.

WWM 8/30/94

P Photo SAN94-P16 and SAN94-P17 show views of the roof of the site and the town of Akrotiri in the distance

P photo SAN94-P18 shows the area to the east of the preceding photo, which is the drainage basin for the ~~sout~~ 8/30/94 small stream that transected the site. (the torrent).

A reconnaissance trip was made to the northern end of the island and Therassia to view Minoan volcanics, and particularly phase 3 deposits which are absent at Akrotiri, although they may have been eroded (after deposition) by phase 4 flooding, etc. Phase 3 deposits are white ash containing many large xenoliths of dark volcanic rock. They are thick and a dominent fraction of the Minoan volcanics on the northern part of the island. Boulders of the phase 4 deposits at Akrotiri could have been derived from such material, while most of the ash was trasported out of the area.

8/30/94

8/31/94 A systematic survey description and photography of the Minoan stratigraphy is initiated in the stream valley to the east of the archaeological site.

The underlying rock has been described on pages 21 and 23 (i.e., SAN94-039).

P It is shown cropping out in photos SAN94-P19 and SAN94-P20 from the west wall of the stream valley. A phase 0 is identified by the archaeologists at the site who accuse the volcanologists of rediscovering it years after they had described it. It is a thin layer - a few centimeters thick at the site - of fine ash. At the east side of the stream valley it is difficult to resolve this phase because of colluvial burial, possible paleosol development, and modern disruption. It does appear that a layer of fine ash with small < 1 cm pumice fragments and dark xenoliths occurs ~~th~~ 8/31/94 below the main phase 1 pumice.

P The pre Minoan tuff, a probable paleosol, the basal fine ash and the phase 1 pumice are shown in SAN94-P21 from the ~~east~~ west valley wall.

12/8/94

8/31/94

8/30/94

The main phase 1 lithology is coarse glassy pumice that is poorly consolidated containing mostly small and) varied xenoliths, many of which are altered and leave halos of colored alteration in the enclosing pumice. (See discussions in 1992 field notes.) It is shown in the ~~east~~ west wall of the stream valley in photo SAN94-P22. AMM 12/8/94

P

P At similar photo SAN94-P23 shows phases 1, 2, and 3 at the same area.

Phase 2 is a white fine ash with few xenoliths. It shows fine layering due to grain/pumice size variations. In contrast, phase 3 contains many/ large, dark xenoliths. Phase three appears in the stream valley wall (west) at about the point where the pre-Minoan is exposed. ~~South~~ NORTH of there it is absent. It rapidly increases to >10 m thickness as if it was deposited in a channel. Photo SAN94-P24 is characteristic of its heterogeneity. AMM 12/8/94

x to the south... AMM 12/8/94

P

P Photo SAN94-P25 shows phase 4 deposits overlying phase 2 ash on the west wall of the valley near its summit.

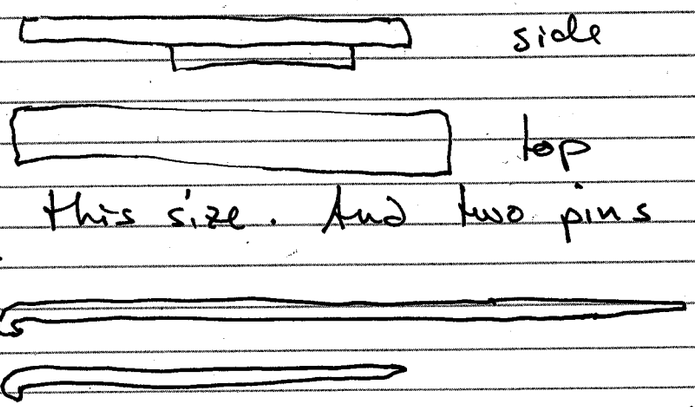
P Photo SAN94-P26 shows details of the phase 4 deposit here.

AMM 8/31/94

Phase 4 looks mostly like a gravel deposit from a flood. I have been using the Sparks and Wilson hypothesis for working purposes, i.e., that the clearly alluvial gravels were deposited when huge waves crested the caldera wall caused by massive caldera wall collapse and wave focusing.

Doumas prefers no further excavation in the southeast end of △3 the wall between △3 and △8 is weak and partially collapsed. △8 has not been excavated - it's filled with debris and ash, and the cellar excavation from △3 is likely to extend under △8 to the south of △3 and possibly under the south wall of △3.

Annie showed me the bronze artifacts that were collected below the square. They consist of a broken chisel:



roughly this size. And two pins

roughly like this.

AMM 8/31/94

(the pins)
She described them as early Cycladic in style as a preliminary identification. She urged me to write to her to request information on bronze chemistry and confirmation of the age of the pins and chisel. The material in the vial described on page 9. This will be referred to as SAN94-050.

The shorter pin C1 is 9 1/2 cm
C3 is 14 cm long (pin)
C2 The chisel is 7 1/2 cm long as broken and 2.7 cm wide.

C1, C2 and C3 are Peggy's reference identification numbers

PEGGY SOTIRAKOPOULOU
35 LASKOU STREET
PAGRATI
11633 ATHENS
GREECE

Peggy would be interested in data on the bronze alteration products.

8/31/94

Gas sampling continues. Numerous samples are being collected from the second sampling site (that of SAN94-002, -004, and -005) to facilitate error-precision-variability analyses.

8/31/94

The tamarisk site is in the field about 100 meters from the roofed site to the southeast. Some isolated tamarisk and eucalyptus trees have been planted in this field. I am told that tamarisk trees are native. The tamarisk gas site is about 1 meter north of the fall line of one of the larger tamarisk trees. The ground is flat and it is likely that it has been used in the past for agriculture, e.g. wine grapes, as many are grown nearby. However, it is now overgrown by dessicated grasses and flowering plants

9/1/94

GAS SAMPLES

number	vial evacuations	flushes: tube	flushes: vial	initial/ date/time	site/ comments
SAN94GAS-006	4	2	3	8/31/94 1:20 PM	same site as -003, -004 and -005 on a hot, sunny, dry afternoon tube not moved since initial insertion
SAN94GAS-007	4	1	2	8/31/94 1:34 PM	same as SANGAS94-006 Photo SAN94-P27 taken of tube as inserted with laboratory as background.
SAN94GAS-008	4	2	4	2:05 PM 8/31/94	See description of tamarisk site on page 31. Tube inserted 45 cm.
SAN94GAS-009	3	0	3	2:15 PM 8/31/94	same as SAN94GAS-008
SAN94GAS-010	4 +2 x 20 cm³ evacuations after flushes	2	3	2:24 8/31/94	at the tamarisk site described on page 31. The tube was pounded to its full length: 75 cm, from the position it was in for -008 and -009
SAN94GAS-011	4	1	2	9/1/94	Tamarisk site at 75 cm; tube unmoved since yesterday.
SAN94GAS-012	4	n.a.	0	9/1/94	Atmospheric air at the Tamarisk site. Photo SAN94-P30 taken at this site

9/1/94

9/1/94

9/1/94 Using a tape measure the locations of the 1993 infiltration boreholes and the 1994 sample and gypsum block boreholes were mapped on the △3 sample location map by triangulation. The orientations of the South and southeast walls was improved on the map. The edge of the cellar on the west side of △3 was marked on the map. And the unexcavated depression on the southeast corner of △3 was also marked.

A copy (trace) of this map was provided to Peggy Sotirakopoulou to document our activities. The original map is attached to this page in an envelope.

Anna Michailidou
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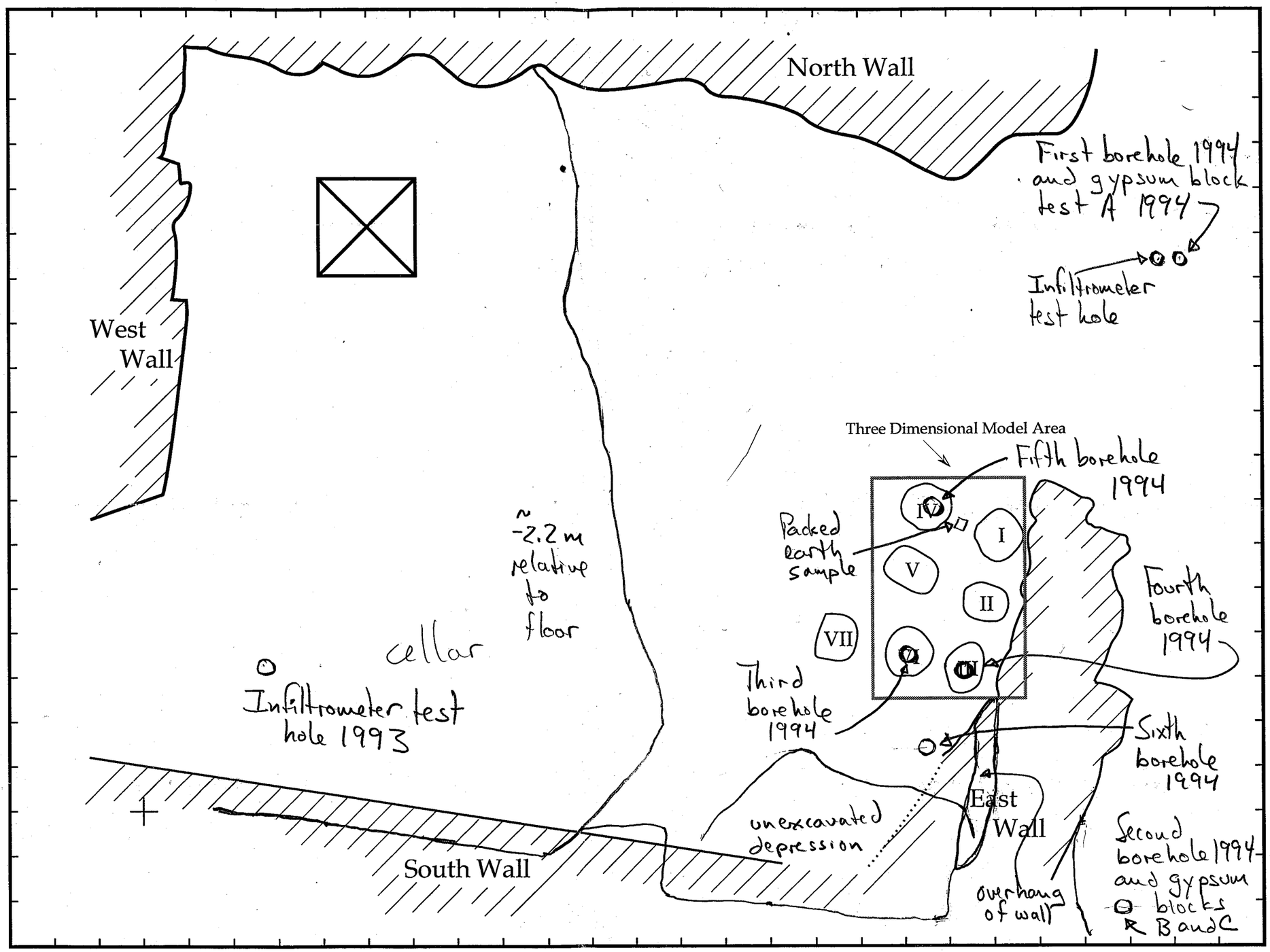
AMM 9/1/94

△3 map 9/1/94 AMM

Δ3 SAMPLE LOCATIONS



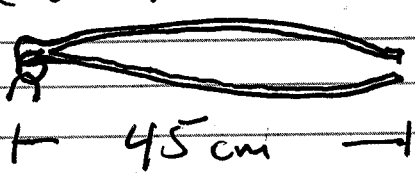
Refined Map of Δ3

WM 9/1/94

On the evening of 8/31/94 Murphy and Green delivered a seminar for about 35 people including Professor Doumas, researchers, and students. The seminar was titled "Relations between Greek archaeology and nuclear waste" and provided an overview of our project at Akrotiri and nuclear waste disposal at Yucca Mountain. There was generally good comprehension and some typical but significant questions about nuclear waste.

On our arrival at the site Anna Michailidou (Annie) invited us to see a bronze artifact collected that day from Q18a, where many artifacts are being found. Apparently it would be impractical for us to sample material around where it was taken because of the density of artifacts (their judgement).

The artifact is a coupled tong



Today Annie gave me the material taken from the surfaces of the artifact. It consists of ash grains and some corrosion products.

GWM 9/11/94

The scrapings from the toung is labelled Δ1 38 a
31-8-94
C023
7375

by the archaeologists. It is our sample SAN94-051.

Some of this material would be useful as a test of corrossion product release from ash by sequential leaching.

Annie showed me a book with some early photos of the site which could help identify what was above Δ3

L'Atlantide la vérité derrière la légende

A.G. Galanopoulos and Edward Bacon

(translated from English)

Albin Michel (French pub.)

Atlantis, The truth behind the legend
1969
Thomas Nelson and Sons, Ltd. London

is the original version

WMM 9/11/94

In this book plate 13 is probably of the valley to the west of the site with the red beach volcanics in the background. WMM 9/11/94
The picture on pg. 162 w/ Marinatos is very early

The picture on 161 shows the cliff below the point where the stream in the small valley to the east intersects that through the site.

Given that the preliminary smoothed Cu plume gives high values near the surface at the north end of the region under the bronzes another packed earth sample was taken between holes I and II of the 1993 season. This is sample SAN94-052.

Ari (site photographer) took a roll of color slides for us of Δ3 and environs prior to disguising our work. The valuable ones will be numbered on viewing. He also took black and white photos for the site archives and will deliver some to us.

Ari requests citation and a copy of any of his photos published.

WMM 9/11/94

Flagstones were placed in two or three layers over the excavated holes in Δ3. A photo was taken
P of the site SAN94-P28. A photo was also taken of Δ8 where the saw and surrounding materials were removed earlier this summer:
P SAN94-P29

P A photo was taken of the "torrent" valley just upstream from the excavation. Although it has an artificial stone wall bank, this may be our last remaining (in the field) indication of the torrent through the site. SAN94-P31

WM 9/1/94

Three photos taken of Δ3 by Ari (see pg. 37) are numbered
SAN94-P32
SAN94-P33
SAN94-P34

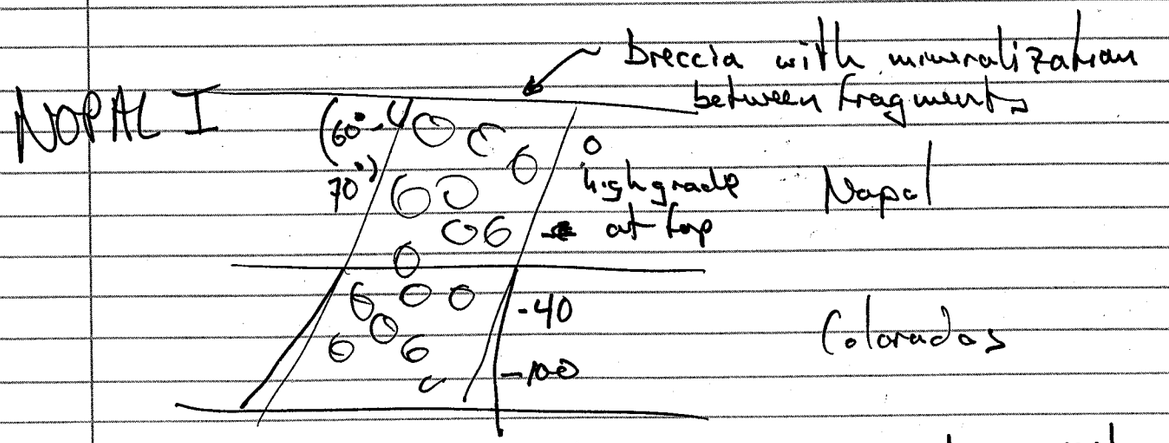
WM 12/8/94

9/17/94 Chihuahua. A large group partially arrived on 9/16 following the NAWG meeting in Santa Fe.

Meeting held after breakfast. Nacho describes regional setting, mining exploration history, and local stratigraphy

37.34my	Mesa Peña Blanca	trachyte - extensive ash flow
	Chonetes	volcanoclastics, fluvial structures + tuff
38.52my	Escuadra	air fall tuff over ash flows
	Pilancillos	volcanoclastics
44.47my	Nopal	U rich unit ash flows massive silicified
	Colorados	(lower Nopal) vitrophyre at top
~53.8my	Corrales	ash flow pink-sandy, oldest ash flow
	Pozos	conglomerate + limestone + volcanics
	Cuervo	unknown age ash flows - folded like Is
	K limestone	

104 U anomalies, work on ~60 sites



WM 9/17/94

Breccia zone at Nopal I

1800 m² at ground surface

628 m² @ -20 17m (-17.26 m)

717 m² @ -40 33m

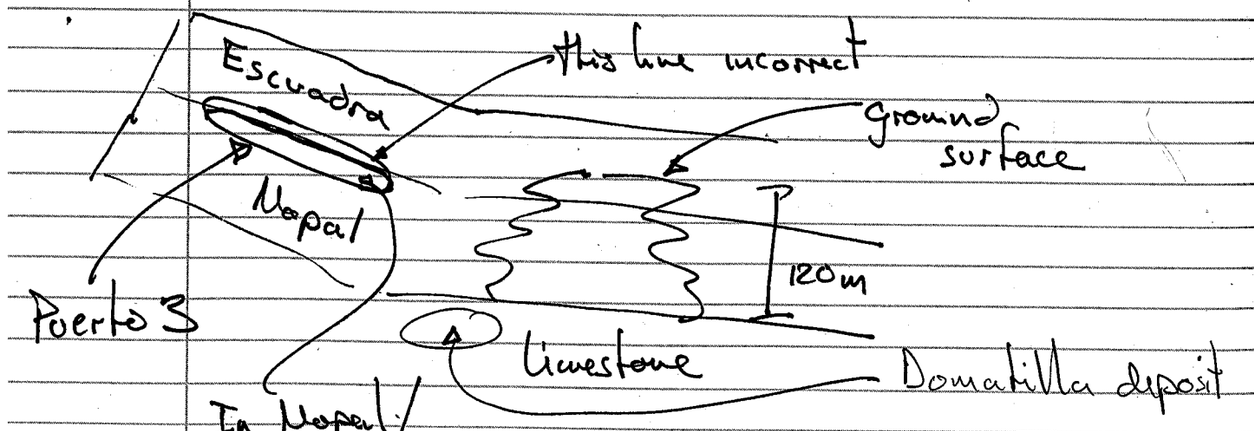
1420 m² @ -70 33 m

2154 m² @ -100 52m

116,000 tons ore / 2.83 kg/ton U_3O_8 MMM 9/17/94

average from 0 to -55 m level
grade decreases below
MMM 9/17/94

Margaritas + Puerto III



50cm to 1m thick MMM 9/17/94

1,300,000 tons } Margaritas
0.088% U_3O_8

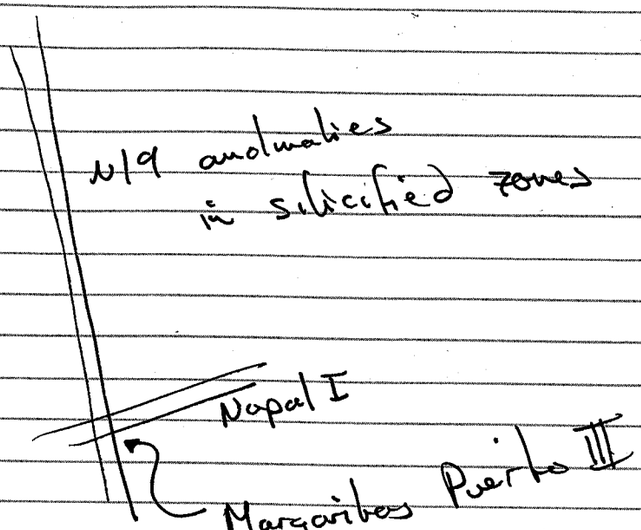
392,000 tons
0.3 to 0.25% U_3O_8 Puerto 3

Most are in Nopal - stratified - mostly in devitrified vitrophyre except at Nopal I

Mesa formation contains high background U and is weathered

Breccia Bulk chem:	level 0	level -40	level -70
% U_3O_8	0.39	0.22	0.34
SiO_2	67.73	70.06	79.58
Total Fe	6.73	6.47	4.29
CaO	0.12	3.22	3.78
H_2O	14.22	13.75	18.72
MgO	1.32	0.66	0.22

MMM 9/17/94



Departure by bus at 9:30 AM from Chihuahua

Three miscellaneous samples collected in the Margaritas pit. One from near and oxidized sulfide bearing zone contains large 2-3 mm quartz crystals. Another contains fine but visible quartz on a surface and the third contains unaltered sulfides in a silicified rock.

9/17/94

Miscellaneous ideas from tour

U chemistry in well in carbonates SE to Nopal I could reflect transport from deposit

Higher U in more mafic trachyte of Mesa formation than in more silicic Nopal I suggests leaching of U from Nopal.

Regional tectonic event at ~5 my in SW US: Sierras, Grand Canyon, leaving regional geomorphic evidence

Arrival at Margaritas at 12:30 PM - 3 hours

In a borehole at Nopal combined neutron and γ logging could provide correlations between water content and mineralization.

9/17/94

August 23 1995 in field at Napal I with David Pickett, Ron Green, Jim Pitkyl, Linda Korach, Ignacio Reyes, and Rob Bowman.

Examination of the seep discovered in 1990 on the north side of the Napal I Cuesta revealed no surface water despite heavy rain in July and occasional light rain subsequently.

Borehole 12 was uncapped and revealed condensation in the PVC casing. Depth to water level is 9.6 meters from the top of the casing. The bottom of the hole is 10.75 - 10.8 m from the top of the casing. Depth to water measured with an electric well probe registering a beep when water is contacted.

"Red line" calibration is checked for YSI Model 33 S-C-T Meter for in situ temperature measurement: 24.5°C is water temperature. Salinity is below detection. Conductivity is 466 µS/cm — drifting to 470 µS/cm.

These values are to be adjusted for calibration. w/ known conductivity soln's. The conductivity is automatically temperature calibrated. 10/23/95

Temperature in-situ in water drifts to 23.5°C.

Probe for T, salinity, conductivity is model LN3422 - borrowed from George Rice, consultant to CNWRA.

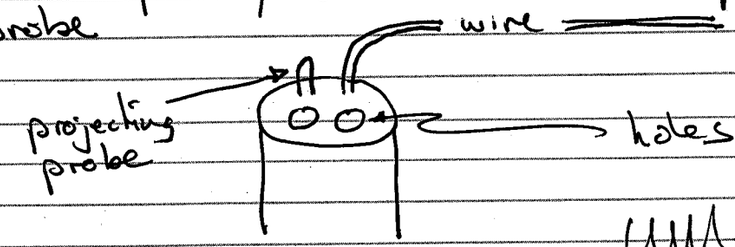
Calibration of YSI S-C-T meter T ~ 30°C by YSI meter and 28°C by secondary probe. Meter adjusted for T compensation for standard.

For 718 µS/cm standard, the meter reads 650 µS/cm bouncing between 620 µS/cm and a bit above 650 µS/cm. Salinity of standard is below detection limit.

Solution used for calibration returned to standard supply solution.

Second standard is 1409 µS/cm Temperatures are 31°C by S-C-T meter and 29°C by secondary probe. (stand alone) Calibrated reading is 1400 µS/cm.

For calibration, standard solutions cover holes in in probe, but do not cover projecting probe.

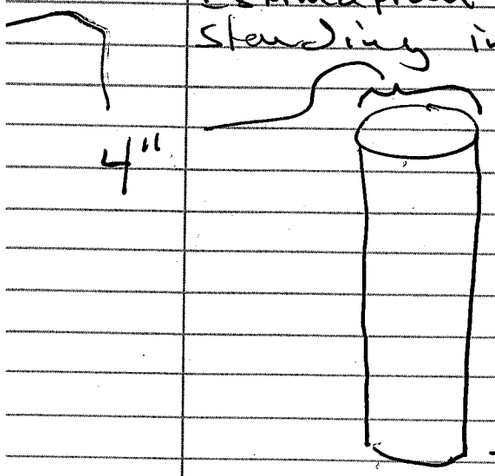


10/23/95

Probe reads higher conductivity when not resting on sides or bottom of beaker containing calibrating solution.

Repeating calibration with 718 µS/cm solution. T = 31°C.
Conductivity - not touching the bottom is 705 µS/cm.

Estimation of volume of water standing in borehole 12.



$\pi \times (2'')^2 \; 2.54^2 \frac{cm^2}{in^2} \; 110\ cm$

$\approx 8918\ cm^3$

≈ 9 liters

3 foot plastic bailer rinsed with purified water and then with nanopure water.

Teflon drop cord for bailer measured to ~9.5 meters so bottom of bailer will not strike borehole base.

MMM 8/23/95

Bailer lowered - not to bottom of borehole and removed. Most of water taken in bailer leaked out in ascent.
Measurements on first water sample:

T = 28.9°C - after some warming at surface
pH = 6.8
Eh = 0 mV

Measurements made with Acumet 1002 meter.

~1/2 of collected water sample used for immediate T, pH, Eh measurements. Remainder saved unfiltered as BH12W95-01. in bottle 21.

Calibration of pH meter in field.
pH 4.00 standard Lot 951736-24
(reading 4.02) - then calibrated
perpHect Buffer 7.00 (eveloped standard)
(reading 6.98) - then calibrated

pH 10.00 standard Lot 953202-24
(reading 9.91) - then calibrated

Calibration of meter for Eh using procedure documented in lab notebook of David Pickett. Quinhydrone redox buffers (QH) ~0.5g in 50ml 4.00 and 6.86 pH buffers. Valid for 24 hours; synthesized at noon 8/23/95.
T for 4.00 QH = 35.9°C
Reading 265 mV
(should be ~253mV) 8/23/95 MMM

6.86 pH; T = 35.2
Reading = 97 mV (should be ~ 72 mV)

Second water sample, ~ 600 ml collected; it is slightly turbid - light brown; with a faint smell of H_2S.

Immediate T = 27.0 w/

Millivolt reading decrease slowed in 90's mV, → stabilized @ ~+92 mV

pH = 6.80 @ T = 28.8°C w/ pH meter probe, @ 12:24 PM

pH = 7.0 @ 29.2°C @ 12:26 ½ PM

(Meter is temperature compensated.)

pH = 7.1 @ 12:27 ⅓ PM @ 29.3°C

pH = 7.2 @ 12:28 ⅓ PM @ 29.4°C

Sample labelled BH12W95-02. in bottle 35

In sample used for pH, Eh measurements
Dissolved O_2 measured by CHEMets color comparison method.
Dissolved O_2 measured @ 5-6 ppm —
This can be regarded as a maximum because of agitation + exposure to air during prior measurements.

8/23/95 MMM

Reference electrode for ORP probe is Ag/AgCl.

Real Eh values are ~ 200 mV higher when referenced to H_2 electrode (?)
Ref: ASTM 1498-93.

Third sample taken at 2:41 PM
BH12W95-03 in bottle 27.

Voltage = 175 mV - steady
T = 26.5°C
pH = 7.55

measurements made with 5 minutes

Water is again turbid - not as bad as -02 probably because of settling over lunch and because bailer was not lowered as deep into hole.

At 252 Sample BH12W95-04 collected in bottle 29.

Cumulative collections
1 ~ 100 ml
2 ~ 600 ml
3 ~ 500 ml
4 ~ 600 ml

1.8 l

Later samples have no clear scent of H_2O - perhaps a little organic/chlorophyl scent to -03.

8/23/95 MMM

For -04

Eh = 167 mV
pH = 7.32
T = 26.4 °C | within 8 minutes

BH12W95-05 collected at 3:00 PM
in bottle 28

T = 24.9 °C w/ Stand alone T probe | within 5 minutes
Eh = 170 mV
pH = 7.26
T = 25.6 w/ meter T probe

The following sample extracted from the borehole 12 was not collected but was used to completely fill a glass bottle which had dosed two "powder pillows" of manganous sulfate and alkaline iodide-azide reagent. It was stoppered without any trapped air. Test designed for dissolved O_2 measurement. Initially light brown-yellow water. Flocculant allowed to settle ~ 20 minutes and reagitated and allowed to settle a second time - still no gas is in stoppered bottle.

Continue O_2 on pg. 52

MM 8/23/95

BH12W95-06 collected at 3:24 in bottle 15.

146 mV
26.1 °C (after ~ 5 minutes)
7.7 = pH (after ~ 8 minutes)

Titration measurement = 43 for CO_2
43 x 2 = 86 mg/lit CO_2

- water collected between -05 and -06 for this as well as dissolved O_2 measurement.

Alkalinity sample collected in the interval ~ 0.1 lit. Plus sample collected and combined w/ later bail to form sample -012.

BH12W95-07 collected at 3:50 PM in bottle 39 ~225 ml.

BH12W95-08 collected in bottle 38 @ 3:55

Eh = 147 mV
T = 26° C
pH = 7.34

BH12W95-09 collected at 4:17 in bottle 40.
BH12W95-10 collected at 4:21 in bottle 17.
BH12W95-11 collected at 4:41 in bottle 7.
relatively turbid water collected near bottom of hole.

MM 8/23/95

DAP 8/23/95

DAP 8/23/95

Phenolphthalein alkalinity = Ø. Did not turn ~~pink~~ pink after addition of phenolphthalein. Add Bromcresol Green-Methyl Red indicator, titrate to "total alkalinity" as below. (pink tint)

Alkalinity measurement titration to 287. mg/lit as $CaCO_3$.

Dissolved O_2 (after adding sulfamic acid powder to dissolve flocculent) (A small bubble present after adding the above) DAP 8/23/95

Reading = 64

64/100 = 0.64 mg/lit

Total hardness 223 mg/lit as $CaCO_3$.

Acidity titration to be conducted on water sample collected ~~prior to~~ → BH12W95-11. after ~~lunch~~ 8/23/95 (at 4:55 PM)

BH12W95-12 collected ~4:50 PM as a composite from two bailed water samples. in bottle 19.

BH12W95-13 collected at 5:03 PM in bottle 34 - increasingly turbid.

Depth to water level after -13 is 10.7 m from casing top. More water remains indicating that the morning estimate of borehole depth was too low.

MW 8/23/95

Acidity

"Methyl orange acidity" = 0

titration yellow → green (supposed to be DAP 8/23/95) per instructions, but started as blue; did not change color after considerable titration DAP 8/23/95

"Total acidity" = ~~80~~ 66 mg/lit $CaCO_3$

MW 8/23/95

On separate batch of sample. DAP 8/23/95

Titration measurements performed according to HACH test kit model AL-36DT

: dissolved oxygen :
CO_2
total hardness
acidity
alkalinity

0.7 liters of turbid water bailed at 5:16 PM and discarded.
0.5 lit of turbid water bailed and discarded at 5:18 PM.
0.3 lit ditto at 5:22
0.25 lit ditto at 5:23
0.2 lit ditto at 5:25

MW 8/23/95

Borehole drained to level that the electronic water depth meter does not work. Depth to water is 11 m from top of casing.

0.15 lit bailed + tossed @ 5:41 PM
0.25 lit " " " @ 5:42
0.1 lit " " " @ 5:44

Tally of water bailed. + chronology

-01	0.1		
-02	0.6		
-03	0.5	.03	
-04	0.6	.03	
-05	0.5	.03	
-06	0.~~4~~ WWY 8/23/95		
-07	0.25		
-08	0.25	.03	
-09	0.25		
-10	0.4		
-11	~~0.~~ 1.0 WWY 8/23/95		
-12	0.5		
-13	1.0		

conserved 8/23/95 @ 600PM (some used for electronics)

excess for electronic measurements

0.3 for O_2
0.15 lit for CO_2
0.1 for alkalinity
? 0.1 lit for hardness
0.2 lit for acidity

8/23/95 WWY

Total water conserved 6.35 lit
+ conserved + used for electronics
Excess for electronics 0.12
Water for titrations 0.85
Water dumped 2.45

Water extracted 9.77

Based on initial estimate of water volume, revised estimate of water depth, there appears to have been limited or no recovery during sampling.

Sample BH12W95-11, a 1 liter sample, is filtered w/ 0.2 μm syringle filters taking samples from top of settled sample. It is acidified w/ 0.5 ml concentrated nitric acid, note ★. The sample of filtered water is collected as BH12W95-11F in bottle 30.

Decanted from BH12W95-11 is an unfiltered sample labelled BH12W95-11UF. Intended for anion analyses, in bottle 62.

Another subsample of BH12W95-11 is decanted by syringe, unfiltered, and acidified. It is labelled BH12W95-11UFA.
★ Concentrated nitric acid: Mallincrodt AR select. 0.5 ml. in bottle 22.
0.4 WWY 8/23/95

WWY 8/23/95

Remainder of BH12W95-11 with sediment is decanted in a small bottle and labelled.

Filters from 0.2 μm filtering of are collected in a package with appropriate label.

Filtering of -011 started around 6:30 PM and ended ~ 8:30 PM.

Filtering of BH12W95-05 started at around 900 PM. The 0.2 μm filtered sample is BH12W95-05F. Filters are collected in a labelled bag. For filtering -05 a separate filter was used for each syringe-full of sample - each syringe holds ~ 60 ml. (For -11, initially two syringes-full were filtered with the same filter.)

BH12W95-05F was acidified with * concentrated nitric acid: 0.25ml. in bottle 26

Remaining -05 sample was separated into

BH12W95-05UFA unfiltered, decanted, acidified in 0.2 ml * nitric acid in bottle 12
BH12W95-05UF unfiltered, decanted, bottle 47
BH12W95-05(residual) - what's left.

8/23/95

One more filtered bottle by 0.2 μm filter / 1 filter per syringe of ~ 50 ml. Original sample is BH12W95-04. Taken adjacent in time to -05 it could be combined as a single sample.

BH12W95-04F is 0.2 μm filtered and acidified with * nitric acid: 0.25 ml. It was collected in bottle 14.

BH12W95-04UFA - unfiltered, decanted, acidified w/0.15ml * nitric acid in bottle 10

BH12W95-04UF - unfiltered, decanted, Bottle 45

Residual collected in bottle BH12W95-04(residual)

Filters collected in appropriately labelled bag.

Filtering exercises terminated at 10:20 PM.

8/23/95

8/24/95 Return to Borehole 12

Depth to water from top of casing is 11.05 m. This indicates that water level dropped 5 cm since final measurement on the evening of 8/23. This can be accounted for by extraction of 0.5 liter of water after the final depth measurement on 8/23.

Height of top of casing above +10⁻ level ground surface is 37 cm.

Move to well in carbonate rocks in valley east of Nopal I. This is the well previously used to estimate the depth of the water table below Nopal I! Sounding with the electric beeper sounder indicates depth to water is 93.9 m from top of well casing. This compares closely to level measured years ago (1990 probably) under much wetter conditions.

At 11:12 AM a ~300 ml sample of water was extracted from the "West Valley Well" and designated WVW95-01. It has a faint brown-orange color. The rope and bailer used to extract it clearly had signs of mud and rust from scraping on borehole and casing walls.

WWW 8/24/95

** At 11:21 T = 29.6 (stand alone probe) Eh = 124 mV relative to Ag/AgCl reference at 11:25.

pH test of probe in 7.00 standard pH solution. Reading is 7.08 at 32.4°C on buffer. Buffer documentation indicates reading should be 6.98. No recalibration of machine was effected.

WVW95-01 water measured at 29.1°C by pH meter probe at 11:29 pH = 8.21 at 11:29½ AM.

Two point calibration effected at pH 7.00 and 10.00.

Sample pH remeasured at 7.49 - 7.51 at 28.9°C at 11:37.

Another sample ~1 liter collected from the West Valley Well by dropping bailer several meters into the water, with a closed stop-cock at the bottom. (Check valve has been malfunctioning.) Sample collected at ~ 11:49 AM and labelled WVW95-02. in bottle 1.

T=
29.5 at 11:52; Eh drops to 67mV then rises,

** (First voltage measurement for sample WVW95-01 - the top hole on the electrode was not openned to air.)

WWW 8/24/95

Eh stabilizes at 73 mV at 11:54

This second water sample is a gray-green color.

T w/ pH probe = 29.3°C at 11:56

pH = 7.72 at 11:57 AM.

Conductivity meter gives 32°C at 12:01 PM

Mesured conductivity = 250 µS/cm. @ 12.03.

WVW95-03 collected at 12:00 is also gray-green and also contains floating particles (leaf parts?)

Redox calibration w/ 4.00 pH QH at 259 mV at 34.7°C at 12:08 PM
with 6.86 QH at 35.0°C at 12.10 PM
mV reading is 91 mV.

AMM 8/24/95

AMM 8/24/95

Sample WVW95-04 was also collected by plunging a stop-cocked bailer, is also gray-green and was split in three fractions initially; one was placed in a gas free glass beaker w/ "powder pillows" added for dissolved O_2 analysis at ~ 12:17 PM; the second in a graduated cylinder for CO_2 analysis; and the third fraction in a 500 ml bottle (number 16).

CO_2 analysis reading 4 → 9 AMM 8/24/95

= 9 → 18 mg/lit CO_2

Flocculent added to O_2 sample - agitated - allowed to settle - agitated - allowed to settle. Sulfanic acid added. This dissolved the flocculant and the solution turned yellow.

Titrated to pale yellow.

Two droppers of indicator - solution turns dark blue.

Titration from blue to colorless yields with 1.03 mg/lit O_2 (dissolved).

Alkalinity measurement

500 mg/lit as $CaCO_3$ comparison sample prepared.

No phenolthalene alkalinity detected.

125 ± 5 mg/lit as $CaCO_3$ alkalinity (total).

AMM 8/24/95

Measurement of total hardness is 106 mg/lit as $CaCO_3$. - corrected below

Titration terminated, but after a minute sitting, color changed back to pink. Additional titrant added and revised/corrected total hardness is 122 mg/liter as $CaCO_3$ - but solution color is still not stable for periods of 10's of minutes.

pH measurement using titration kit colorimetric method. = 8.0 ± 0.5 measured on WW95-04 at 1:50 PM. - Data indicate pH a little lower than 8

2:50 PM: No significant variation in BH12 water level - 11.05 m from cap.

BH11 has water heard by dropped stone but is obstructed - precluding sounding

BH10 - only 2 m from BH12 has no water at 10.5 m depth from ground level, which is ≈ BH12 depth.

BH13 - no water at 11.3 m depth from ground surface

BH14 - no water

No water observed in any other borehole on the +10 level.

8/24/95

About 10 m south of BH-12 is a hole in the +10 m surface which is about 1 m deep. Reyes says that this hole is the base of a shaft that existed above the +10 level prior to its excavation. Water has been diverted off the +10 level into this hole by some crude ditches. The +10 level also tends to slope to the north away from its rim above the +0 level. After rain storms this hole partially fills with water providing relatively long term positive head and recharge potential. Water in BH12 may well derive from this local recharge. According to Reyes, in May 25 1995 the shaft base hole was piled full of brush, and the brush burned. Charcoal fragments and discolored rock are apparent. According to Reyes, in July 22 1995 there was heavy rain and the shaft base hole was partially filled with water. This water could contain chemical components (K^+?, PO_4^{4-}?) indicative of the fire that could be detected as tracers in BH12 water.

EC
1/5/97

A previously unobserved hole (borehole) about 1 m west of borehole 12 was opened. It contains water at a depth of 11.3 m below the ground surface. The ground surface is 45-50 cm below the casing top on BH 12. So water level in the new hole is clearly deeper than the bottom of BH 12, which is approximately 11.1 - 0.5 = 10.6 meters below the top of the newly observed hole

E.C. Pe 1/3/97

I have reviewed this Notebook and find it in general compliance with QAP 5.001. There is adequate information for another qualified person to repeat the activity.

E.C. Pe

1/9/97

This project has ended because the U.S. government decided to try to balance its books more closely.

E.C. Pe

1/9/97