Salton Sea Scales

Binocular Microscopic Descriptions And Bulk X-Ray Diffraction Analyses of Scales from the Salton Sea Geothermal Field: Region 2 Turbo, Early March 2001

For

William Osborn
CalEnergy Operating Company
7030 Gentry Road
Calipatria, CA 92233

By

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Energy & Geoscience Institute
423 Wakara Way, Suite 300
Salt Lake City, UT 84108

Introduction– Three scale samples from the Region 2 Turbo, Salton Sea geothermal field, Imperial Valley, CA, were submitted to the Energy & Geoscience Institute (EGI) for examination and X-ray diffraction (XRD) mineralogic analysis by CalEnergy Operating Company's William Osborn on Thursday, March 29, 2001. Two of the samples were labeled as having been collected at the "GE Rotoflow by Weyman" on March 8, 2001. The third sample was labeled as "inner adjusting ring, metallic deposit at [words obliterated] seal" with the date of collection noted as January 19, 2001. Descriptions and analytical results for these three samples are as follows:

1. ***MCS rear cover -- Sampled at GE Rotoflow by Weyman, 03/08/01**

   Very light gray to white, fluffy-textured powder (particles probably average <5 microns), with <0.1% disseminated, subequant, matte to submetallic, opaque, medium reddish-gray to dark gray particles <20 microns in diameter. Also about 1% opaline/metallic flakes, angular, up to 0.5 mm wide but <50 microns thick, light gray, and translucent to nearly opaque – some of these flakes have striated surfaces, with the striations visually straight and parallel, and therefore likely to be casts of the surface on which the scale precipitated. The surfaces (one surface only) of some of

3. Inner adjusting ring, metallic deposit at [word obliterated] seal -- 01/19/01, 09:00

A mix of several different types of fragments ranging in shape from platy to chunky to elongate-subrounded; in color from brownish-red and orange to slightly reddish steel gray; and in texture from earthy (reddish and orange fragments) to metallic (steel-gray plates and chips). The sample comprises three main fragment types:

Fragment type 3a -- Flat-planar to curviplanar flakes, up to 20 X 15 mm wide, and ranging in thickness from 20 microns to 0.4 mm (average thickness about 0.15 mm). The flakes are opaque, dull to shining, glassy to submetallic to metallic-lustred, and medium, slightly reddish gray in color. These flakes have two very different types of surfaces. One surface type is relatively smooth, shiny, and is striated in one direction only. The striae have about 20 microns of relief, trough to crest. Major striae are about 0.5 mm apart; intervening minor striae only about 10-30 microns apart. The striae could be casts of milling marks on the scale substrate. The obverse surfaces of these flakes are highly irregular, and commonly consist of recemented fragments, both chips and stubby-elongate particles. These "lumpy" surfaces are in part clearly opaline, but are dominated by an earthy- to powdery-textured, medium to dark gray metallic phase, identical to the substance making up *type 3b* particles (see immediately below).

Fragment type 3b – These account for about 40% of the total sample. The fragments, up to 25 mm in length or diameter, are principally angular but less commonly subrounded (abraded-looking), and are composed of porous, earthy to submetallic, dark brownish- to reddish-gray iron oxide. A few of these particles also contain scattered clots of a pale brassy metallic mineral, probably a sulfide.

Fragment type 3c – Accounts for about 35% of the sample total. Similar to type 3b, but much more porous and very limonitic in appearance. These samples are mottled, earthy-textured, and consist of aggregates of bright brownish-red, brownish-orange, and (more rarely) brownish-yellow iron oxide intergrown with clots of dark reddish-gray submetallic iron oxide identical to that which forms *type 3b* particles. Much of the limonitic portion of these fragments occurs as rosette-like aggregates that are earthy to perhaps slightly adamantine in luster.

Bulk XRD analysis shows that this sample consists of magnetite (MM)*, akaganeite (mm), opal-A (mm-M), possibly minor arsenic sulfide (?), and possible traces of fluorite (?), calcite (?), and dolomite (?). There are probably many more substances present in very minor amounts, but the reflections corresponding to these materials are subdued, poorly developed, and overlapping, hindering accurate identification by XRD alone.

General Observations and Interpretations – Initial scale deposition on this inner adjusting ring appears to have been a combination of opal and iron oxide formed directly on what could be a milled surface. The scaling appears to have been relatively quiescent, resulting in a smooth siliceous and iron-rich coating (now seen as *type 3a* particles). Thereafter, the depositional environment appears to have become agitated, resulting in local disruption of the early-formed material, then deposition and recementation of the resulting fragments on the initially-deposited "smooth scale." The cemented fragments then were coated with a powdery submetallic iron oxide. The latter forms layers up 0.1 mm thick on the interiors of the opaline flakes (the smooth scale), and we can only conjecture that continued build-up of the substance resulted in formation of a thicker layer later disaggregated to form *type 3b* particles. The relationship of *type 3c* particles to the others is not immediately apparent. Neither of the two other particle types has large amounts of type 3c material adhering. Either the type 3c limonite formed at another location on or near the adjusting ring, or it was deposited very loosely (easily detached) on a precursor type 3b substrate. The rosettes described above, intimately associated with the powdery limonitic material (almost certainly akaganeite), conceivably could be arsenic sulfide, but the myriad overlapping reflections in the XRD pattern for this sample preclude confident identification of this phase in the absence of corroborating chemical data.

phone Will Osborn
11-3-00

bulk sample

is arsenic in dark stuff

in other plants – As in glass – good. leach tests required.

in citric acid pH=5 show As stays in glass – doesn't leach out.

Region 1:

when Elmore – 100 back in system, this problem started

– I think when cleaned out / opened up deep feed → deep, hot, high salinity.

shallow feed is – oxidizing + dilute

mixing and then ppt the black arsenides.

seed the brine with silica

the clarifier – where precip. silica in a big tank

– filter press the slurry at btm

this is what I got.

whole bulk w/ all the silica

probe or SEM

[illegible]

$ 15,000/day to dispose of As-scale

760 348-4214 new office Will Osborn

Ag – .25 ppm brine

Au – not detectable

PGE like Au

Rhodium can see low ppb

Sue Lutz - notes on
Will Osborn's GRC talk

GRC

Will Osborn - 9-26-00

Zn - 500 ppm   fluids
30,000 tons x $ 30 million /yr
.50 lb =

Mn EMD -   9.5-10%
1500 ppm x   of world
[illegible] =   demand

electrolytic
MnO_2

Li   → $LiCO_3$
x
$5.00/lb =

---

lithium "way more than
the world demand"

Subject: **Re: scale study**
Date: Tue, 21 Dec 1999 12:18:21 -0700
From: "Sue J. Lutz" <sjlutz@egi.utah.edu>
Organization: Energy & Geoscience Institute
To: Melinda.Wright@calenergy.com

Howdy Melinda,

I just got the thin-sections and polished sections (for future microprobe work) back yesterday for the production scales. I looked at them briefly and am kind of dissappointed- they appear to be predominantly amorphous banded iron silicate without much sulfides or other opaques. The scales from Elmore-12 and Sinclair-10 are all orange-brown (oxidized-ferric?) iron silicate with some patches of green (reduced-ferrous?) similar-looking stuff. The scale from Sinc-11 may actually be more interesting- it consists of fragments of the iron silicate scale that are cemented by a very fine opaque material. (And, of course, it's the one I didn't get made into a polished section because it looked so grungy as a hand sample.)

So, that's as far as I've gotten. We can do the XRD easily, but I'm not expecting any great results from the bulk mineralogy (mostly amorphous anyway). I'm guessing that the most variation within the scales and the best characterization will be at the elemental level, and that we will need to do the microprobe work on the very fine-grained opaques.

Hope things are going well for you down in the desert. It's snowing here, but just flurries, the skiing's still no good (I'm a powder hound).

Lunatics will enjoy the big, bright moon tonight,
Sue

Melinda.Wright@calenergy.com wrote:

> *Hi Sue,*
> *How are things going in SLC? It's a balmy 75 here! I just wanted to get*
> *an update from you on the scale project. No rush, just wanted to see*
> *what's been accomplished, and if you have a tentative schedule.*
> *Have a good Christmas and a happy and safe Y2K*
> *Melinda*

November 2, 1999

Susan Juch Lutz
Energy and Geoscience Institute
423 Wakara Way
Salt Lake City, UT 84108

Dear Sue,

Enclosed are three scale samples we talked about on the phone Monday.

Well	Well Type	Date	Depth	Comments
Sinclair-10	Production	7/21/99	?	Sample collected from survey tool
Sinclair-11	Production	2/24/99	?	"
Elmore-12	Production	4/30/99	?	"

Sinclair-10 and Sinclair-11 are located in the Region 1 area of the field (southwest) and Elmore-12 is located in the Region III area (north). The brine produced from the Sinclair wells contains about 23 wt.% TDS and Elmore-12 produces about 30 wt.%. I will provide brine analyses from these wells at a later date.

Let me know if you need additional information or have any questions.

Sincerely,

Melinda Wright
Geochemist

CALENERGY OPERATING CORPORATION
A MIDAMERICAN ENERGY HOLDINGS COMPANY AFFILIATE
950 WEST LINDSEY ROAD · CALIPATRIA, CALIFORNIA 92233 · 760-348-4000 · FAX: 760-348-2714

Melinda Wright 11-1-99:

3 production scales — sending

- downhole (not piped).
- titanium-cased wells
- small

2 from Sine — low TDS (small samples) } contrast diff. fluids.
1 Region 3 — high salinity.
(big samples).

- talked to Wil Osborn after GRC
- (she did go to geochemistry workshop)

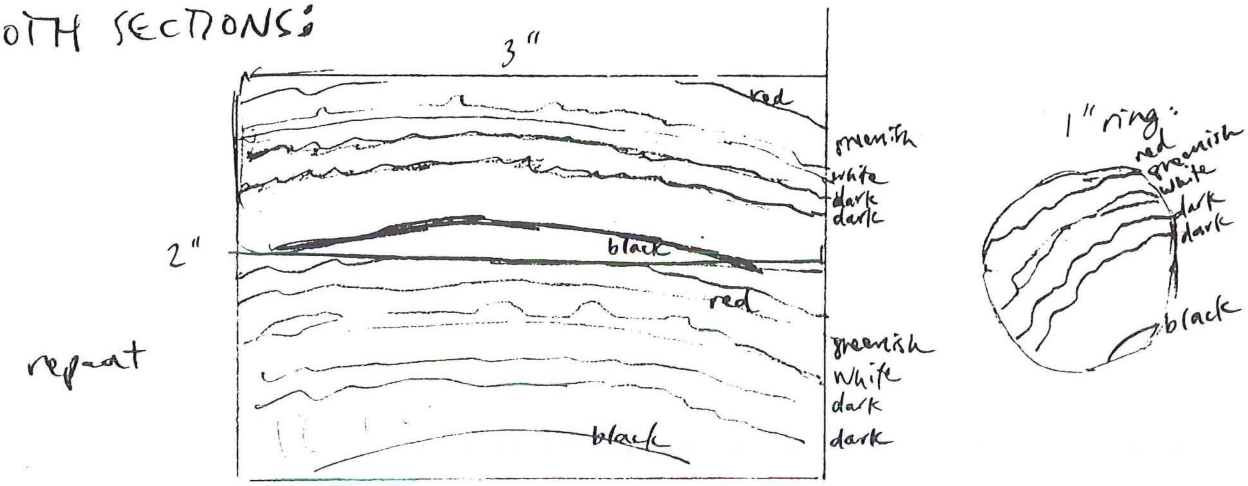
10-15-99

TO BE DONE:

SALTON SEA INJECTION SCALES	COVERED OVERSIZED THIN-SECTION 2x3"	POLISHED SECTION 1" ring mounted w/epoxy
SINC-26 9/2/98	X	X X MAKE TWO TO GET ALL THE ZONING
	COVERED STANDARD THIN-SECTION	
ELMORE-101 6/14/99	X	X

AL -

FOR SINC-26, PLEASE TRY TO GET SOME OF THE BLACK MATERIAL ON THE INSIDE OF THE PIPE SCALE FOR BOTH SECTIONS. WISH TO HAVE ALL THE BANDS/ZONING REPRESENTED IN BOTH SECTIONS:



I'M SURE YOU'LL DO YOUR USUAL BEAUTIFUL JOB. THANKS. SUE

SECTIONS TO ME:
SUE LUTZ
EGI - UNIV. OF UTAH
423 WAKARA WAY

INVOICE TO:
DEE PETTY
(SAME ADDRESS)
UCS P.O. # 18343

September 17, 1999

Susan Juch Lutz
Energy and Geoscience Institute
423 Wakara Way
Salt Lake City, UT 84108

Dear Sue,

Enclosed are two scale samples to start off the project.

Well	Type	Date	Process	Depth (ft)
Sinclair 26	Injection	9/2/98	pH mod	3602
Elmore 101*	Injection	6/14/99	pH mod	4250-4500

*Elmore 101 is an unwashed cutting sample. If you need more sample I can send an adjacent depth interval.

I thought we would begin with pH mod wellbore injection scale. That way we can focus on our worst scale problem from the reservoir standpoint. Sinclair 26 and Elmore 101 are located in the Region 1 area of the field (southwest). The brine injected into these wells contain about 26wt.% TDS and have a pH between 3 and 4. I can send injection brine analyses taken prior to the well clean out if needed. I'm still looking through our storage for additional samples. I'll send those along as soon as I can.

Let me know if you need additional information or have any questions.

Sincerely,

Melinda Wright
Geochemist

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4 kinds of scale:

Melinda Wright
8-30-99

2 kinds of injection:

① pH mod — add HCl to brine — low pH at injection.

② CRC —
crystallizer-reactor-clarifier

2 other production wells:

③ titanium-cased wells

④ reg. carbon-cased wells

has about 10 samples now

zoned samples - 3 about

Melinda at GRC — geothermal geochemistry workshop

Unocal Geothermal Division
Unocal Corporation
P.O. Box 1805
Indio, California 92201
Telephone (619) 342-4723

UNOCAL 76

January 19, 1989

Ms. Susan Lutz
Earth Science Laboratory
Univ. of Utah Research Inst.
391 Chipeta Way Suite C
Salt Lake City, Utah 84108

Dear Susan –

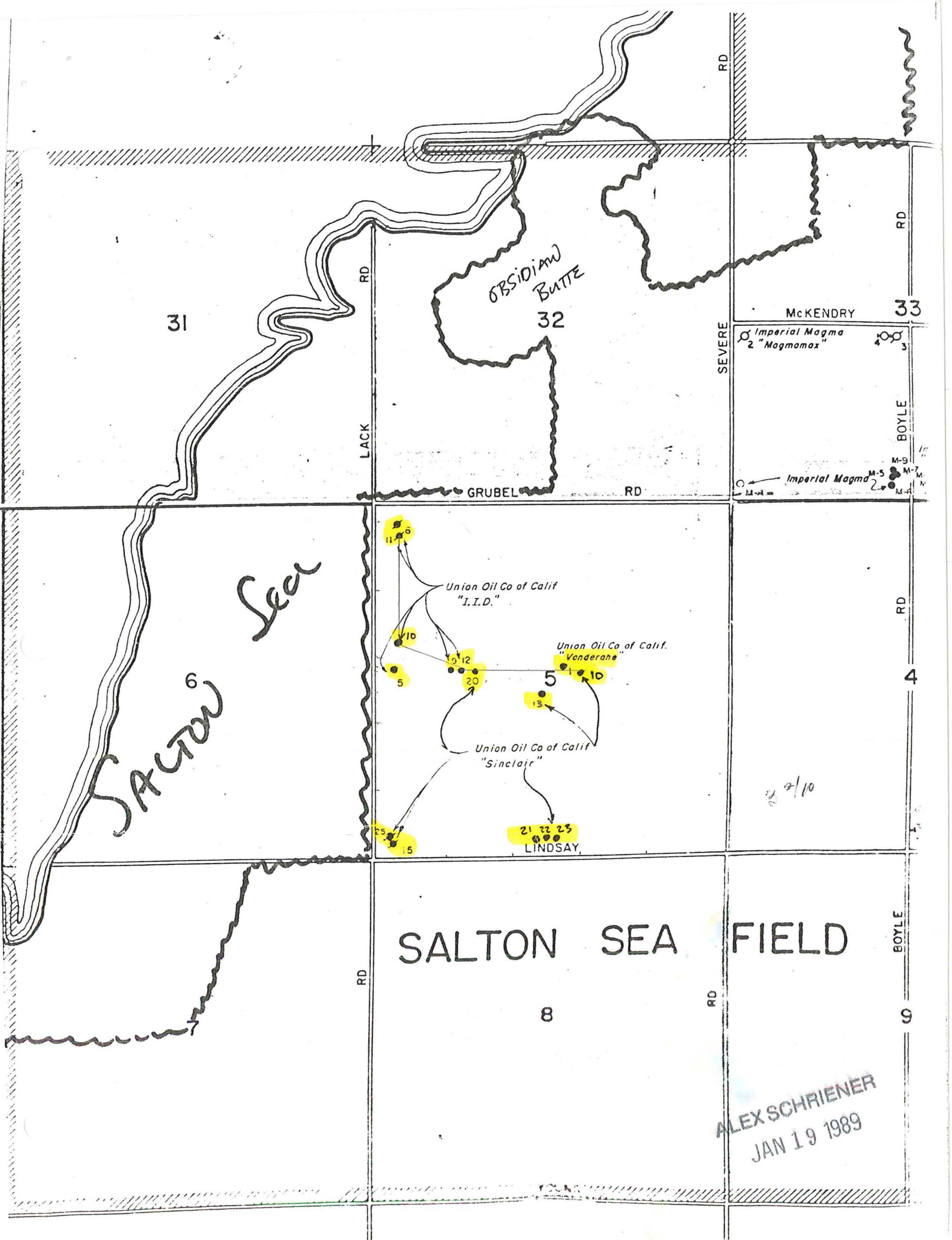
Thank you for the update on the Salton Sea XRD–Petrography project. From what told me, it sounds like everything is going along fine. Your idea of sending me the worksheets when they are completed is great. I assume your final report will be in late Feb or early March.

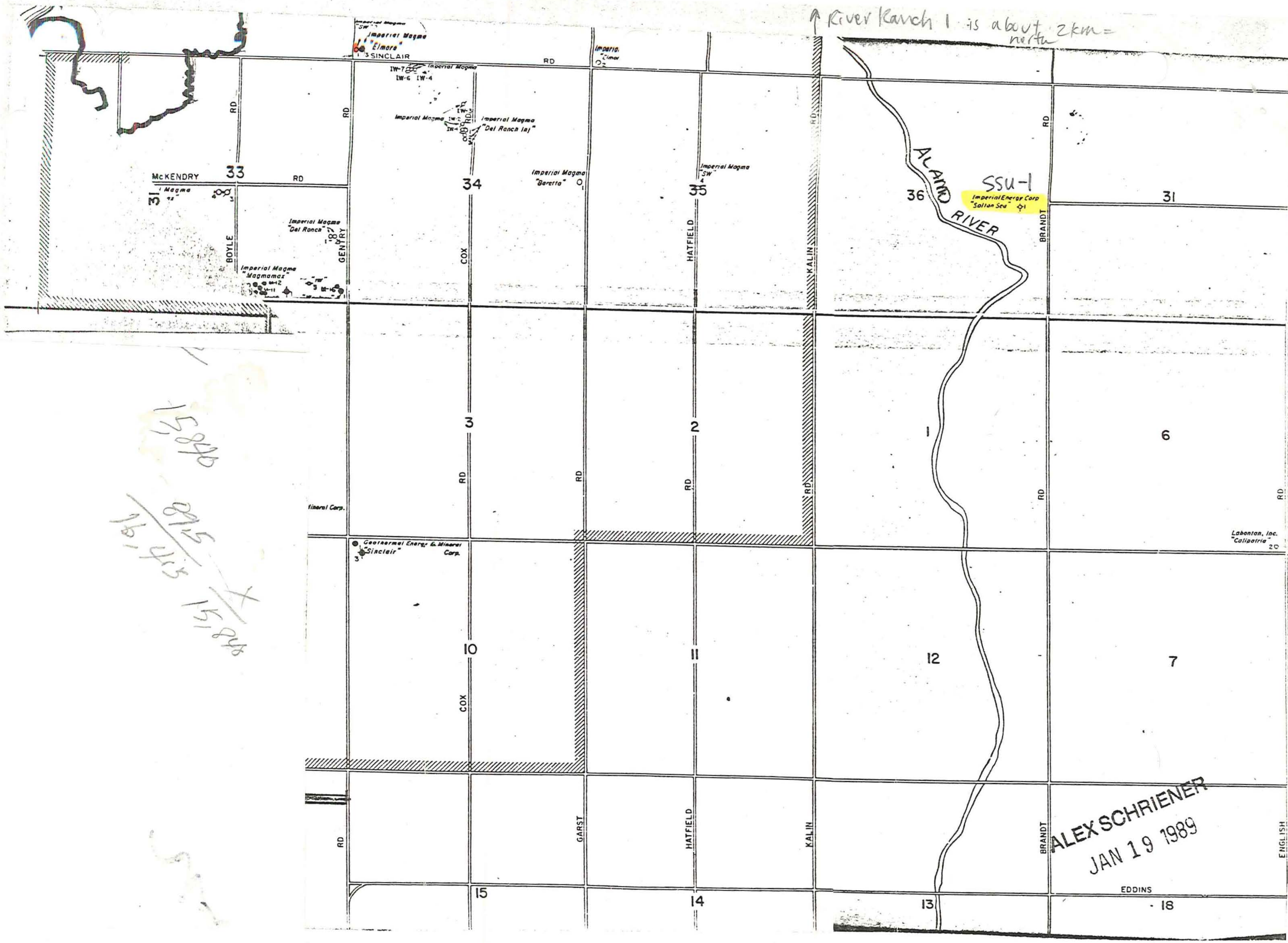
Attached is the well location map you requested. I used an old Calif. Division of Oil and Gas map as a base. As you can see the SSU-1 well is located about 3½ miles to the East of the Sinclair & IID wells.

I should explain something about the well I sent you in late December; well 8-1. This well is not located in the Salton Trough, although it does have similar sort of rocks. I may not have made this point clear to you or Joe Moore. Please tell Joe so he will not be confused on the well 8-1.

Sincerely,

Alexander Schriener


SALTON SEA FIELD
31
32
33
4
5
6
7
8
9
OBSIDIAN BUTTE
SALTON Sea
RD
LACK
RD
SEVERE
RD
BOYLE
RD
BOYLE
McKENDRY
GRUBEL
RD
LINDSAY
Imperial Magma
"Magmamax"
Imperial Magma
Union Oil Co of Calif
"I.I.D."
Union Oil Co of Calif.
"Vonderahe"
Union Oil Co of Calif
"Sinclair"


↑ River Ranch 1 is about 2km = north
Imperial Magma "SW"
Imperial Magma "Elmore"
SINCLAIR
RD
Imperial "Elmor"
IW-7 IW-6 IW-4
Imperial Magma
Imperial Magma "Del Ranch Ia)"
McKENDRY
33
RD
34
Imperial Magma "Baretto"
Imperial Magma "SW"
35
36
ALAMO RIVER
SSU-1
Imperial Energy Corp "Salton Sea"
31
Magma
Imperial Magma "Del Ranch"
GENTRY
BOYLE
Imperial Magma "Magmamax"
COX
HATFIELD
KALIN
BRANDT
3
2
1
6
Geothermal Energy & Mineral Corp. "Sinclair"
Mineral Corp.
Lobonton, Inc. "Calipatria"
10
11
12
7
GARST
ENGLISH
15
14
13
EDDINS
18
ALEX SCHRIENER
JAN 19 1989
15,840
895
16,415
15,840
X

Petrographic Summary

Sample Designation – RR-18 Liner Scale

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 29, 2000

Megascopic Description – Slightly yellowish, very light to dark gray, botryoidally banded, metallic scale with common elongate, pointed, prismatic crystals forming convex-outward, radiating bundles and sheaves. Crystal size highly variable from band to band, ranging from <5 microns to several mm. Interior of the scale sample (concave inward) is sieve-textured and incorporates obvious clastic debris.

Petrographic Description – The sample consists of three major bands, each divisible into a number of subtle subzones. The inner band (concave-inward), conspicuously sieve-textured, averages about 7 mm in width, and has a curvature with a radius of about 20 mm. This band has subequal amounts of loellingite ($FeAs_2$) and a combination of clastic debris, carbonate, and minor smectite. The clastic debris comprises uncommon rounded grains of mudstone and siltstone embedded in a matrix of fine sandstone, in turn cemented by calcite with minor quartz and adularia. The larger clastic grains reach 2.5 mm in diameter; the typical grain diameter is about 0.1 mm. The carbonate cement along with some plagioclase grains and volcanic (?) rock fragments are partially altered to euhedral prismatic epidote; the volcanic grains, in addition, are partially altered to chlorite. The clastic grains and debris are surrounded by and incorporated in a sieve-textures loellingite matrix. This arsenide matrix occurs as partial to complete rosettes of radiating slender pointed prismatic crystals averagin about 40-60 microns X 10-15 microns in size. The rosettes have coalesced to form a loose, loellingite network. Open spaces in this network are partially filled with microcrystalline (about 0.2 mm), late-stage calcite, which in turn is locally coated with brownish smectite. The smectite does not seem to have a coherent crystal structure, but instead seems to be smeared on the calcite and on some clastic grains and loellingite. It is suspected that the smectite is a residuum from drilling fluid, but this possibility must be investigated further for confirmation.

Scale Sample RR-18 Liner Scale, ***Petrographic Description***, continued

The central band of this scale sample is 7-15 mm thick, with curvature indicating a radius (to the outer surface of the band) of 35-40 mm. This band is slightly sieve-textured (about 7% holes, many filled with calcite) and has a botryoidal "cauliflower" appearance. There are at least six sub-zones within this band, defined by differences in crystal size and density as well as pore space. Crystal sizes range from practically colloidal (<<1 micron) to perhaps a few tenths of a millimeter, although it is difficult to judge for certain without a polished section. One filled crack (?) between two major bundles of radiating loellingite crystals contains a subrounded, bronze metallic mass about 1 mm in diameter; it is coated with thin layer of loellingite. Identity uncertain but a reasonable guess would be pyrrhotite (assuming it is a common phase). Cavities between loellingite crystals and crystal bundles are generally filled with late-stage, microcrystalline calcite. The cavities are irregular, and range from a few microns to a few tenths of a millimeter in maximum dimension.

The outer band of the scale sample 7-12 mm in width, and has curvature (outer margin) indicating a radius of about 50 mm. This band grades from a very thin inner zone of dark metallic gray microcrystalline loellingite (?), to an outer zone which dominates the band and consists of sieve-textured, outward-pointing bundles of loellingite crystals up to 3 mm X 1 mm, and in bundles up to 5 mm in width. Again, former pores between arsenide crystals are generally filled with late-stage, microcrystalline calcite.

Petrographic Summary

Sample Designation – Injection well Sinclair-26, Salton Sea geothermal field

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 29, 2000

Megascopic Description – 25-30 mm-thick composite scale sample, dominated by botryoidally-banded opal. Thin, dark, interior band, concave-inward (toward smaller radius), 1-2 mm thick, partially consisting of a resinous to vitreous-appearing subopaque, deep orange-brown substance with coppery-orange internal reflections. Probably at least 30-40 individual bands of opal, with different colors and textures depending upon density, porosity, and admixed or co-precipitated other minerals. Much of the opal is ligh gray and microporous, resembling a fine pumice. Other opal is dense and vitreous. Some of the opal appears to incorporate clastic grains and small rosettes of clay.

Petrographic Description – Dark interior band is the most complex. It consists of several subzones described as follows. The innermost subzone is about 0.2 mm thick, consisting of botryoidally banded, bright brownish-orange, isotropic to very feebly birefringent, iron-rich silica, possibly admixed with some amorphous hydrous iron silicate (hisingerite). The next outer subzone is 20 to 50 microns thick, and consists entirely of microcrystalline (<<1 micron) iron oxide (?magnetite?). Next outward is a 0-20 micron wide band of the same orange opal as in the innermost band. Next is another 20-50 micron-wide band of the microcrystalline iron oxide. Next outward is a 0.1-0.8 mm wide band consisting of intergrown, iron-rich opal and arborescent masses of loellingite and magnetite (and possibly other metallic phases). With increasing distance from the innermost layers, the apparent iron content of the opal diminishes (less orange in coloration).

The next major band is discontinuous but up to 3 mm thick. It consists dominantly of porous opal, lightly iron-stained, in which are embedded about 2% micro-rosettes of apparent nontronite. It is possible that these have crystallized from hisingerite admixed with the opal, rather than from the opal itself. This band also contains about 0.1% disseminated clastic magnetite grains <20 microns in diameter. Also a trace of disseminated clastic quartz and plagioclase.

The remainder of the sample is defined by botryoidal opal bands ranging in color from cream to dark greenish-gray, and in thickness from 50 microns to 7 mm. Variations in the color of the opal are due to (1) porosity differences; (2) varying amounts of clastic magnetite with traces of hematite, both likely derived by scale disaggregation; and (3) the content of greenish nontronite, which occurs as disseminated rosettes up to 50 microns in diameter seemingly encapsulated in opal spheroids. 3-5 mm inward from the outer surface of this scale accumulation is a 2-mm band of opal which has been stained brick red by iron oxide. The outer surface of the scale accumulation is very rough and nubbly, with relief of 2-3 mm.

Comments, Interpretations – The XRD pattern for this composite scale sample is dominated by the so-called "silica hump" corresponding to opal. There may also be amorphous iron silicate admixed with the opal, but this cannot be determined from petrographic and XRD investigation alone. Estimate about 2% magnetite (visual estimate – XRD indicates about 1%). Also a trace of loellingite in the inner, more iron-rich band. Estimate visually about 7% nontronite rosettes (corresponding exactly with the XRD estimate). Quartz and plagioclase are present in amounts totalling about 1%. There may be a small amount of halite, but this identification must be considered extremely tentative.

Petrographic Summary

Sample Designation – Injection well Elmore-101, Salton Sea geothermal field

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 30, 2000

Megascopic Description – Porous, light gray to pale reddish-gray masses consisting of angular clasts of opal and rock debris, medium- to coarse sand size, loosely cemented in a powdery, matte-textured, pale gray to reddish-gray clay-like matrix.

Petrographic Description – (Sample utilized for thin section apparently washed, with consequent removal of the clay-like matrix described above). Entire sample consists of angular clasts, up to at least 3 mm in diameter (avg. about 1.5 mm in diameter), of the following types (in decreasing order of abundance): (1) clear to cloudy-appearing but unstained opal, dense, botryoidal, delicately banded, with the bands commonly distorted by the effects of slumping and soft-sediment deformation pre-solidification; (2) pale brown opal, commonly showing evidence of at least three periods of deposition. Some of these clasts are cut by microveinlets of clear opal, which it it is the same as [1] establishes an age relationship; (3) argillaceous arkosic siltstone; (4) fine-grained, arkosic sandstone; (5) orange to red, amorphous iron oxide, commonly containing clasts of both types of opal described above; (6) microcrystalline magnetite, commonly intergrown with or encapsulated in reddish amorphous iron oxide; (7) free grains of quartz, plagioclase, rock fragments, and carbonate.

Comments, Interpretations – The pale matrix is believed to have been simply finely pulverized opal, but possibly including a small amount of smectite.

Petrographic Summary

Sample Designation – Production well Sinclair 10, scale chips

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 29, 2000

Megascopic Description – Chips, up to 10 mm in diameter. Dark brownish gray, with luster resinous on broken surfaces, submetallic on depositional surfaces. Slightly translucent, with deep red to red-orange internal reflections. Hackly to subconchoidal fracture. Botryoidal texture especially apparent parallel to depositional layering. Apparent healed dessication cracks, as if the material was initially a gel.

Petrographic Description – Chips are translucent orange-brown to red-brown, moderately to strongly birefringent (though birefringence masked by "body color"). Chips oriented perpendicular or oblique to depositional layering consist of laterally coalesced, fibrous, outward-expanding bundles. Chips oriented parallel with depositional layering have a texture reminiscent of the scales on butterfly wings. Layering distinctly botryoidal, with individual layers ranging from <1 micron to 0.15 mm (avg. about 50 microns). Crystallization has taken place across the depositional banding (that is, the crystal bundles encompass more than one band). Most chips are disrupted by networks of healed, interconnected, randomly-oriented, apparent dessication cracks. These cracks are filled with the same material making up the bulk of the sample, but with lower birefringence.

Comments, Interpretations – The bulk X-ray diffraction pattern for this sample corresponds to a very poorly-crystalline, trioctahedral smectite (060 peak at 1.53A; 001 peak at 14-15A). Because of the color of the scale, it is likely that this smectite is nontronite, but chemical analysis is recommended for confirmation. The smectite almost certainly crystallized from a gel-like state, accounting for the reticulated dessication-crack pattern. The sample is so poorly crystalline that laboratory smectite standards cannot be compared for reliable quantification. The entire sample, however, is more or less birefringent, so it is unlikely that X-ray amorphous material is present to any great extent.

Petrographic Summary

Sample Designation – Production well Sinclair 11, Salton Sea geothermal field

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 30, 2000

Megascopic Description – Dominantly chunks of an earthy to pulverulent, light orange-brown material in which are embedded sand-sized clasts of a dark resinous to submetallic gray substance along with other grains of unknow origin and affiliation. Along with the earthy material are thin flakes and plates of dark brownish-gray, resinous to submetallic material, up to 10 X 7 X 1 mm in size. This substance is subopaque, and some flakes appear to have a dull "root-beer-glass" colored internal reflection. Fracture is subconchoidal to hackly. This appears to be the same substance occurring as clasts in the earthy material.

Petrographic Description – Aggregate of 20 micron to 0.3 mm diameter (avg. 0.2 mm diameter) clasts, subrounded to angular, embedded in a deep brownish-red to orange-brown, opaque, microcrystalline (<<5 micron), nondescript aggregate. The clasts are translucent, bright yellow-brown to orange-brown, and moderately to highly birefringent. They were clearly disaggregated from larger masses deposited incrementally as botryoidal layers. Some of these chips are disrupted by healed dessication cracks. Many consist of radiating bundles of micron-sized flakes and fibers. There are also a few scattered chips, same size as the brown ones, but composed exclusively of microcrystalline carbonate. One or two clastic quartz and feldspar grains as well.

Comments, Interpretations – The X-ray diffraction pattern for this sample corresponds to a very poorly-crystalline trioctahedral smectite, which based upon the color of the sample is most likely nontronite. The poorly crystalline nature of this layer silicate is such that it cannot be quantified reliable using our laboratory XRD standards. Based on its petrographic characteristics, however (e.g. almost all birefringent), it is highly likely that the nontronite dominates the sample (perhaps >80 wt %). There is also a trace of quartz (clastic) and carbonate (probably a disaggregated scale component). Possibility of 1-2% magnetite, based on small, ill-formed reflections at 2.53Å and 2.97Å.

Petrographic Summary

Sample Designation – Production well Elmore-12, Salton Sea geothermal field

Type of Sample – Geothermal scale

Examiner – J. Hulen

Date – July 30, 2000

Megascopic Description – Chips, up to 12 mm in diameter. Color ranges from dark brownish gray through slightly greenish, medium brownish gray, to pale brown (rare). Two main textures. Darker material is botryoical, subopaque (though without internal reflection), matte to resinous-textured, and distinctly fibrous, with fibers and fiber bundles oriented roughly perpendicular to depositional banding. Lighter material is opaque, matte to erratically resinous, locally porous, with apparent microspherulitic texture.

Petrographic Description – Two distinct types of chips represented. One type is dense, massive, dull orange-brown to yellow brown in color, translucent, and distinctly botryoidal and fibrous. In cross section, the fibrous texture is made up of coalescing and radiating bundles, up to at least 1 X 0.1 mm, composed of elongate flakes and fibers typically 20-40 microns long and 2-5 microns wide. The long axes of the small flakes and fibers are oriented so that they make angles of 20-25° with the long axes of the fiber bundles. Delicate to vague banding locally present. Individual bands a few microns to a few tenths of a millimeter in width. Scattered through some of these chips are irregular patches in which the clay is translucent greenish-gray and less birefringent than the brownish-colored variety. Also disseminated amongst the flakes and fibers, and of about the same size and shape, are elongate crystals of a pale yellowish-white metallic mineral. There are also local concentrations of this metallic phase as <10 micron wide, discontinuous streaks along the boundary between one botryoical band and another.

A second textural variety is represented by chips with a cellular structure. The cells are up to 3 mm in maximum dimension, and range from round to ovoid to irregular to amoeboid. Cell walls are 0.3-1 mm thick, deep reddish- to orange-brown, microcrystalline, and subopaque. Cell interiors are partially filled with more coarsely crystalline layer silicate aggregates that are pale to medium greenish gray. Much of this material has been plucked from the thin section.

Both textural varieties of this material are sparsely to extensively disrupted by networks of randomly-oriented, healed dessication cracks.

Comments, Interpretations – The two types of chips in this sample as seen petrographically correspond to the dark-dense and spherulitic textures observed megascopically. The dessication cracks in both types of chip indicate that the material crystallized from a gel-like state. The layer silicate phase is shown by X-ray diffraction analysis to be a trioctahedral smectite, most likely nontronite. The disseminated metallic phase is loellingite. There are several small, insignificant, and vaguely developed reflections along with the obvious ones corresponding to the clay and the arsenide.

The poorly crystalline nature of the nontronite and loellingite in this sample prevents reliable quantification of these phases (their crystallinities do not correspond to those of our laboratory standards). The nontronite, however, would appear petrographically to dominate the sample, and the loellingite to account for less than a tenth of the sample.

RR-18 FeAsprobe.x ↑ from Ray's file

Table 3.

sample	1a	1b	1c	1d	1e	1f	1g	1h
Element (wt %)								
As	70.197	69.459	69.546	69.218	69.578	69.534	69.57	68.777
Fe	26.509	28.73	28.255	28.427	27.122	28.079	27.91	28.197
Cu	1.584	0.754	0.597	0.603	0.971	0.645	0.824	0.434
Bi	0.369	0.787	0.496	0.562	0.615	0.794	0.803	0.538
Sb	0.313	0.698	0.454	0.639	0.375	0.523	0.675	0.533
Ba	0	0.056	0	0	0.169	0	0.202	0
Ag	0.022	0	0.03	0	0.032	0	0	0
Au	0	0	0.177	0.177	0.216	0	0.207	0.029
total	98.994	100.484	99.555	99.626	99.078	99.575	100.191	98.508

sample	2a	2b	2c	2d	2e	2f	2g	2h
Element (wt %)								
As	69.465	68.488	70.077	69.825	69.146	70.505	68.045	22.655
Fe	28.199	28.557	27.299	27.058	29.089	26.664	27.844	19.895
Cu	0.63	0.224	1.299	1.344	0.467	1.416	0.571	6.401
Bi	0.326	0.066	0.431	0.808	0.51	0.412	0.994	0
Sb	0.665	0.629	0.431	0.392	0.448	0.352	0.817	0
Ba	0	0.011	0	0	0.157	0	0.09	0
Ag	0.009	0.02	0	0.045	0	0.009	0.06	0.022
Au	0	0	0.108	0	0	0.03	0.029	0
total	99.294	97.995	99.645	99.472	99.817	99.388	98.45	48.973

1i	1j	1k
69.794	69.451	68.809
27.509	27.079	27.312
1.127	1.095	0.733
0.628	1.038	1.548
0.61	0.509	0.734
0.101	0.169	0.113
0.037	0.082	0
0	0	0.039
99.806	99.423	99.288

2i	2j
36.066	44.494
15.431	22.712
2.028	3.295
0	0.206
0.032	0.326
0.022	0.079
0	0.009
0.01	0
53.589	71.121

scalewholerock.xls
↑
from ALS-Chemex

Table 1.

sample	SIN-10	SIN-11	El-12	RR-18
major elements (wt%)				
SiO_2			37.95	1.16
TiO_2			<0.01	<0.01
Al_2O_3			3.08	0.26
Fe_2O_3			30.53	35.64
MnO			0.33	0.03
MgO			6.15	0.09
CaO			0.85	3.82
Na_2O			2.28	0.56
K_2O			0.96	0.22
P_2O_5			<0.01	0.09
LOI			12.93	39.84
subtotal			95.06	81.71
Cl (ppm)			16000	5460
S (%)			0.03	0.92
Total				
minor elements (ppm) except where noted				
Ni			85	370
Co			35	2420
V			80	<20
Cu			30	8280
Pb			<5	45
Zn			320	20
Bi			<10	9660
Mo			<5	35
W			<20	<20
As			140	65.40%
Sb			60	3600
Ag			3	33
Au			0.385	233.0g/t
Ga			53	<1
Gd			<0.1	0.3
Rb			73.4	8.6
Cs			23.3	1.3
Ba			40	<20
Sr			93.5	72
Y			<0.5	5
Dy			<0.1	0.4
Er			<0.1	0.4
La			<0.5	0.5
Ce			<0.5	1
Nd			<0.5	0.5
Eu			<0.1	<0.1

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Total Pages : 1
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CERTIFICATE OF ANALYSIS A0028005

SAMPLE	PREP CODE		Al_2O_3 %	CaO %	Cr_2O_3 %	Fe_2O_3 %	K_2O %	MgO %	MnO %	Na_2O %	P_2O_5 %	SiO_2 %	TiO_2 %	LOI %	TOTAL %	Ba ppm
DUBM 32999-6	248	226	0.67	0.24	< 0.01	0.81	0.06	1.18	0.04	0.15	0.01	2.36	< 0.01	24.05	29.57	27.5
DUBM 32999-88	248	226	6.97	0.87	< 0.01	5.92	0.11	1.00	0.21	0.15	0.09	54.63	0.38	10.13	80.46	67.0
DUBM 52000-5	248	226	4.38	0.80	< 0.01	58.17	0.95	0.58	0.01	0.14	0.55	30.17	0.28	1.36	87.39	>10000
SSEL-12	248	200	3.08	0.85	< 0.01	30.53	0.96	6.15	0.33	2.28	< 0.01	37.95	< 0.01	12.93	95.06	100.5
SSRR-18	248	200	0.26	3.82	< 0.01	35.64	0.22	0.09	0.03	0.56	0.09	1.16	< 0.01	39.84	79.71	26.0

*MATERIAL NOT SUITABLE FOR ICP/WHOLE ROCK ANALYSIS. Eu DET. LIMITS RAISED. Ba INTF.

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SAMPLE	PREP CODE		Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Hg ppm	K %	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm
DUBM 32999-6	299	233	60	0.23	>50000	< 20	< 5	140	0.20	40	8120	< 10	3470	0.58	10	< 0.01	0.72	290	< 5	0.06	>50000
DUBM 32999-88	299	233	25	2.48	27700	40	< 5	60	0.72	5	1665	< 10	7930	4.12	< 10	0.01	0.44	1560	10	0.06	>50000
DUBM 52000-5	299	233	< 1	0.67	170	10520	< 5	10	0.65	< 5	15	< 10	85	12.15	< 10	0.13	0.28	40	5	0.06	230
SSEL-12	299	233	3	1.86	140	40	5	< 10	0.71	< 5	35	< 10	30	21.3	< 10	0.83	3.66	2410	< 5	1.76	85
SSRR-18	299	233	33	< 0.01	>50000	< 20	< 5	9660	2.77	< 5	2420	< 10	8280	23.4	< 10	0.12	0.05	230	35	0.35	370

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SAMPLE	PREP CODE		Ce ppm	Cs ppm	Co ppm	Cu ppm	Dy ppm	Er ppm	Eu ppm	Gd ppm	Ga ppm	Hf ppm	Ho ppm	La ppm	Pb ppm	Lu ppm	La / 46
DUBM 32999-6	248	226	1.0	1.8	7500	3250	0.3	0.1	< 0.1	0.2	< 1	< 1	< 0.1	0.5	< 5	< 0.1	5
DUBM 32999-88	248	226	30.0	0.9	1640	7270	11.2	6.6	2.1	9.9	12	4	2.3	14.5	200	1.0	[illegible]
DUBM 52000-5	248	226	56.0	5.4	28.0	65	3.8	1.6	< 5.0	4.5	8	1	0.7	45.5	< 5	0.1	41
SSEL-12	248	200	< 0.5	23.3	32.0	5	< 0.1	< 0.1	< 0.1	< 0.1	53	< 1	< 0.1	< 0.5	10	< 0.1	n.a.
SSRR-18	248	200	1.0	1.3	2350	8570	0.4	0.4	< 0.1	0.3	< 1	< 1	0.1	0.5	< 5	< 0.1	1.7

Oct 3 00
left message for Howard Sharer
- need over As
- Au?

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SAMPLE	PREP CODE		P ppm	Pb ppm	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
DUBM 32999-6	299	233	< 100	185	730	< 5	45	< 0.01	< 20	< 20	20	< 20	480
DUBM 32999-88	299	233	< 100	320	110	< 5	< 5	< 0.01	< 20	< 20	320	< 20	425
DUBM 52000-5	299	233	2500	< 5	70	< 5	160	0.02	< 20	< 20	20	20	< 5
SSEL-12	299	233	< 100	< 5	60	< 5	100	< 0.01	< 20	< 20	80	< 20	320
SSRR-18	299	233	< 100	45	3600	< 5	70	< 0.01	20	< 20	< 20	< 20	20

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SAMPLE	PREP CODE		W ppm	U ppm	V ppm	Yb ppm	Y ppm	Zn ppm	Zr ppm	Cu %	Ni %	Co %	S % (Leco)	Fe %	As %	Pb %
DUBM 32999-6	248	226	< 1	27.5	25	0.1	3.0	425	1.5	0.340	>20.0	0.734	< 0.01	0.7	>10.00	< 0.02
DUBM 32999-88	248	226	7	264	530	6.0	77.5	510	156.0	0.840	9.53	0.166	0.04	4.4	2.95	0.02
DUBM 52000-5	248	226	18	8.0	75	1.1	19.5	5	66.5	0.010	0.010	< 0.002	0.39	40.8	< 0.01	< 0.02
SSEL-12	248	200	< 1	< 0.5	95	0.1	< 0.5	300	< 0.5	0.005	0.005	0.002	0.03	20.7	< 0.01	< 0.02
SSRR-18	248	200	23	< 0.5	< 5	0.3	5.0	< 5	3.5	0.860	0.015	0.242	0.92	24.5	>10.00	< 0.02

La / 46

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SAMPLE	PREP CODE		Nd ppm	Ni ppm	Nb ppm	Pr ppm	Rb ppm	Sm ppm	Ag ppm	Sr ppm	Ta ppm	Tb ppm	Tl ppm	Th ppm	Tm ppm	Sn ppm
DUBM 32999-6	248	226	0.5	>10000	< 1	0.1	2.4	0.1	68	49.3	< 0.5	< 0.1	< 0.5	< 1	< 0.1	< 1
DUBM 32999-88	248	226	25.5	>10000	4	5.0	2.6	7.7	33	23.0	< 0.5	1.9	< 0.5	3	1.0	< 1
DUBM 52000-5	248	226	19.5	310	4	5.8	26.8	3.8	< 1	353	< 0.5	0.7	< 0.5	1	0.1	19
SSEL-12	248	200	< 0.5	60	< 1	< 0.1	73.4	< 0.1	< 1	93.5	< 0.5	< 0.1	< 0.5	< 1	< 0.1	2
SSRR-18	248	200	0.5	385	< 1	0.1	8.6	0.1	42	72.0	< 0.5	< 0.1	< 0.5	< 1	< 0.1	< 1

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SAMPLE	PREP CODE		Zn %	Cl NAA ppm
DUBM 32999-6	248	226	0.11	< 100
DUBM 32999-88	248	226	0.08	< 100
DUBM 52000-5	248	226	< 0.01	< 100
SSEL-12	248	200	0.03	16000
SSRR-18	248	200	< 0.01	5460

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32499-6
32499-8B

SAMPLE	PREP CODE		Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Hg ppm	K %	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm
DUBM 32999-6	299	233	60	0.23	>50000	< 20	< 5	140	0.20	40	8120	< 10	3470	0.58	10	< 0.01	0.72	290	< 5	0.06	>50000
DUBM 32999-88	299	233	25	2.48	27700	40	< 5	60	0.72	5	1665	< 10	7930	4.12	< 10	0.01	0.44	1560	10	0.06	>50000
DUBM 52000-5	299	233	< 1	0.67	170	10520	< 5	10	0.65	< 5	15	< 10	85	12.15	< 10	0.13	0.28	40	5	0.06	230
SSEL-12	299	233	3	1.86	140	40	5	< 10	0.71	< 5	35	< 10	30	21.3	< 10	0.83	3.66	2410	< 5	1.76	85
SSRR-18	299	233	33	< 0.01	>50000	< 20	< 5	9660	2.77	< 5	2420	< 10	8280	23.4	< 10	0.12	0.05	230	35	0.35	370

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SAMPLE	PREP CODE		P ppm	Pb ppm	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
DUBM 32999-6	299	233	< 100	185	730	< 5	45	< 0.01	< 20	< 20	20	< 20	480
DUBM 32999-88	299	233	< 100	320	110	< 5	< 5	< 0.01	< 20	< 20	320	< 20	425
DUBM 52000-5	299	233	2500	< 5	70	< 5	160	0.02	< 20	< 20	20	20	< 5
SSEL-12	299	233	< 100	< 5	60	< 5	100	< 0.01	< 20	< 20	80	< 20	320
SSRR-18	299	233	< 100	45	3600	< 5	70	< 0.01	20	< 20	< 20	< 20	20

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SAMPLE	PREP CODE		Au ppm FA+AA	Au FA g/t	As %
DUBM 32999-6	244	--	not/ss	-----	22.7
DUBM 32999-88	244	--	< 0.005	-----	-----
DUBM 52000-5	244	--	0.010	-----	-----
SSEL-12	244	--	0.385	-----	-----
SSRR-18	244	--	>10.00	233.0	65.4

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RERUNS from A0028005

SCANNING ELECTRON MICROSCOPY ANALYSIS

Introduction and Analytical Procedures

Scanning electron microscopy (SEM) analysis was conducted on four samples representing scale material collected from a Salton Sea geothermal well. A sample information summary is presented below:

Table 1. SEM Sample Information

Sample No.	*Sample Type*	*SEM & EDX Analysis*
RR 18	metallic chips	✓
SS SIN 10	black glass fragments	✓
SS SIN 11	brown, friable opal	✓
SS EL 12	black glass fragments	✓

A representative sampling of each sample group was mounted on a standard SEM mount and carbon coated for approximately 30 seconds. The samples were then placed in a Leo 440i scanning electron microscope equipped with an Oxford energy dispersive x-ray spectrometer (EDX) for concurrent elemental analysis. All samples were examined and photographed at a range of magnifications to document the morphology and mineral distribution of the sample fabric. Black and white digital images are presented at the end of the report.

Summarized Results

Sample RR 18

A freshly broken surface of this tightly crystalline sample exhibits a metallic luster in macroscopic view. Under the SEM, the surface reveals a banded fabric of densely packed, interlocking crystals (Plate 1) adjacent to more bladed, fibrous, and porous textures (Plates 2 and 3). In the smooth, densely crystalline bands, concurrent EDX analysis yields well-defined elemental peaks for iron (Fe) and arsenic (As) only, indicating the presence of a pure Fe-arsenide compound (Plate 1). More porous bands include bladed and equant, euhedral crystals of Fe-arsenide intermixed with calcite (Plates 3). EDX spectra in these areas include prominent peaks for Fe, As, and Ca. Testing the surface of the duplicate sample with dilute HCl acid confirms the presence of calcite.

Sample SS SIN 10

In macroscopic view, sample SS SIN 10 comprises several black, highly angular, glassy fragments. At high magnification under the SEM, fragments are composed of a dense, opaline glass thinly coated by a discontinuous film of subhedral to euhedral calcite (Plates 4-6). Microcrystalline calcite rhombs are also intermixed with opal spherules on fragment surfaces.

Concurrent EDX analysis yields prominent peaks for Si, O, Fe, and Ca, indicating the presence of Fe-rich glass and calcite. Localized minor peaks for S, Al, Na, and Zn suggest incipient clay alteration and the possible presence of sphalerite or a sulfate mineral.

Sample SS SIN 11

Macroscopically, this sample is rust-brown, microcrystalline, highly porous, and very friable. SEM imaging reveals a loosely crystalline, microporous texture dominated by opaline silica (glass) and Fe-oxide minerals (Plates 7-9). EDX spectra are characterized by prominent peaks for Fe, Si, and O, and discrete particles containing only Fe and O (Fe-oxides, Plate 9) are present in the glassy matrix. Minor elemental peaks for Na, Mg, Al, S, Cl, Ca, and Zn may indicate trace amounts of replacive clay, calcite, and sulfides.

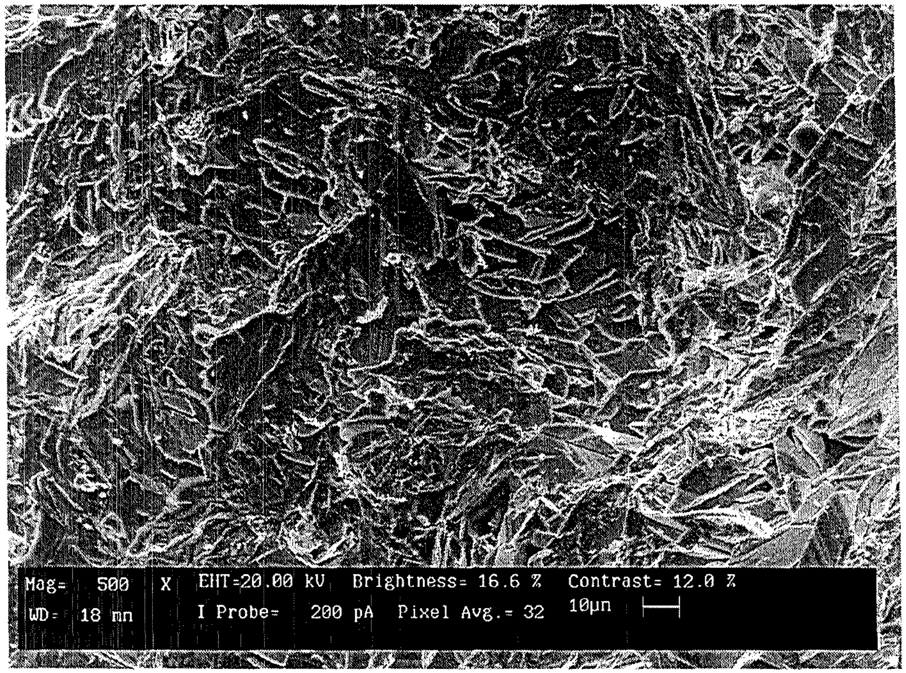
Sample SS EL 12

Dark, angular, concoidally fractured glass fragments comprise sample SS El 12 and are macroscopically similar to those of sample SS SIN 10. Under the SEM, fragments are uniformly composed of dense, Fe-rich glass that is thinly and discontinuously coated with opal spherules (Plates 10 and 11). EDX spectra indicate dominant elemental peaks for Si, O, and Fe (Plate 11). No evidence of clay alteration or calcite mineralization is visible.

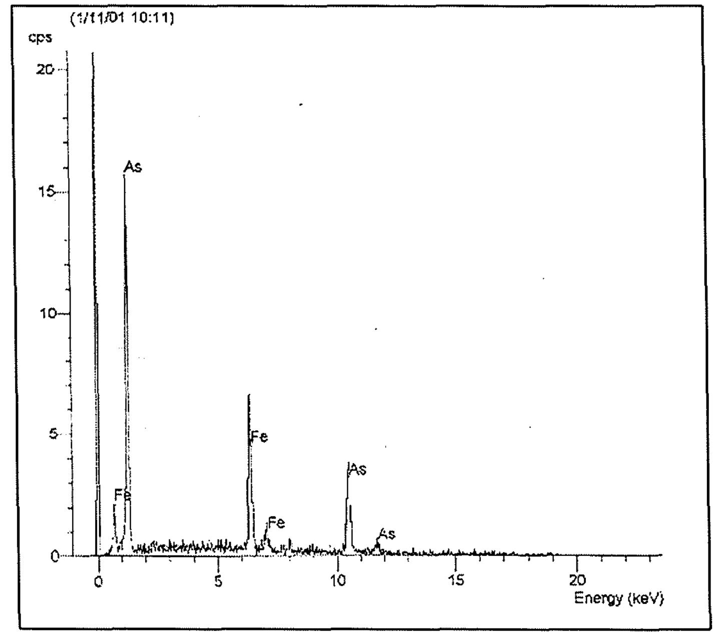
SCANNING ELECTRON MICROSCOPE IMAGES

Note: For report formatting, images are presented at 45% of their original size.

PLATE 1
Sample RR-18



Low-magnification overview of sample texture. Tightly crystalline, interlocking fabric comprises bladed and equant crystals of nearly pure Fe-arsenide. Glassy, amorphous material and clays are absent and porosity is rare. Scale bar = 10 μm. (225×)



EDX spectrum collected from the image at left reveals the dominance of Fe-arsenides and the absence of siliceous material.

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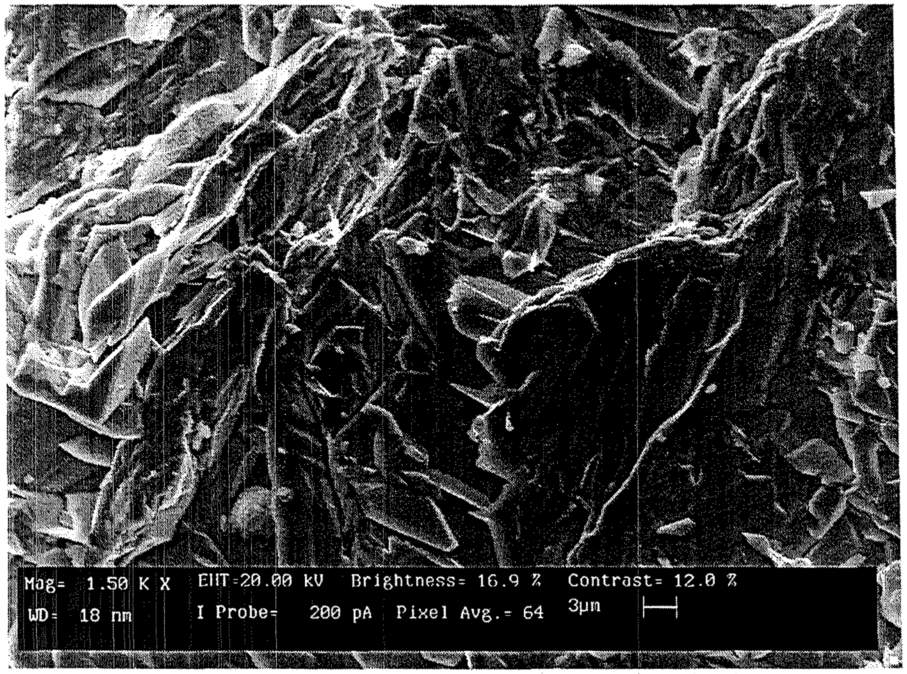
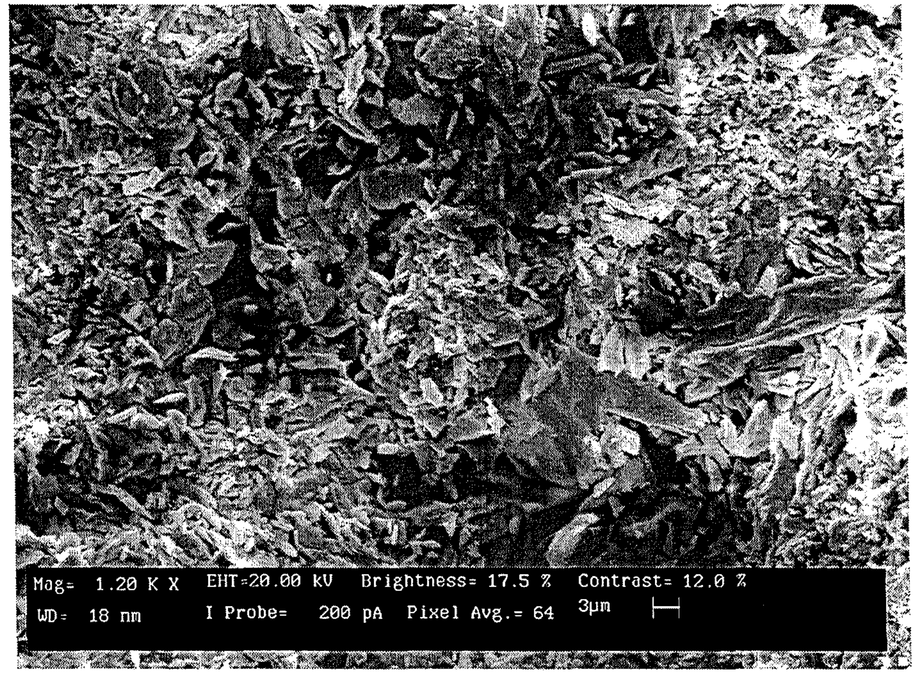
PLATE 2
Sample RR-18

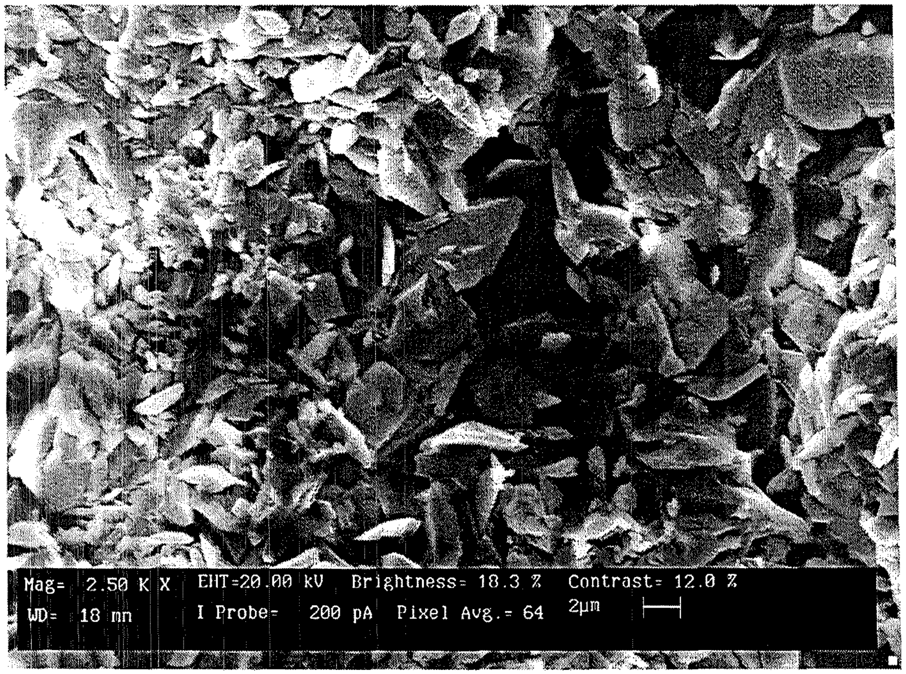


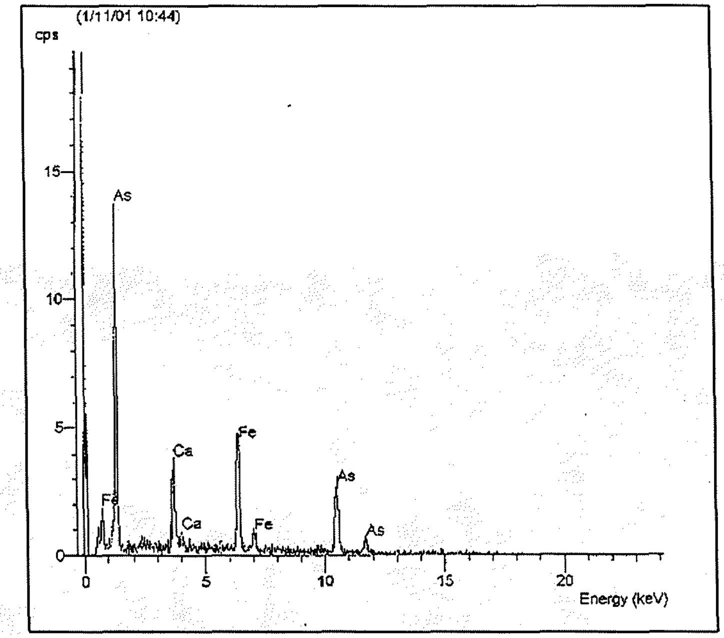
Higher-magnification view of the image presented on the previous plate. Interlocking, subhedral to euhedral crystals of Fe-arsenide dominate the texture and composition. Scale bar = 3 μm. (675×)



Slightly varying texture is more loosely crystalline and includes abundant bladed and tabular crystals. Fe-arsenides are the dominant mineralogic components, although minor calcite may also be present. Scale bar = 3 μm. (540×)

PLATE 3
Sample RR-18

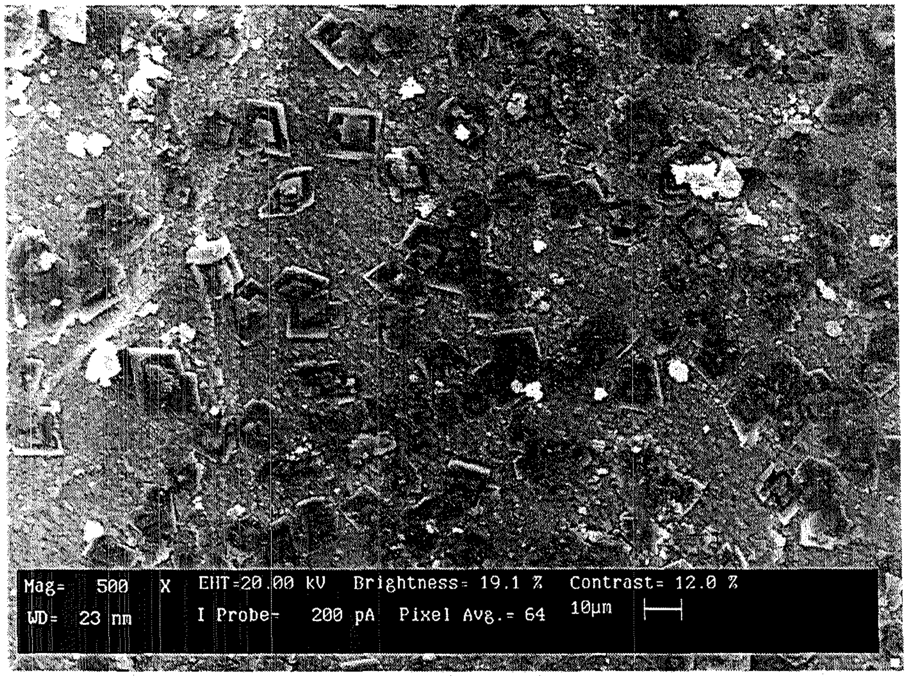




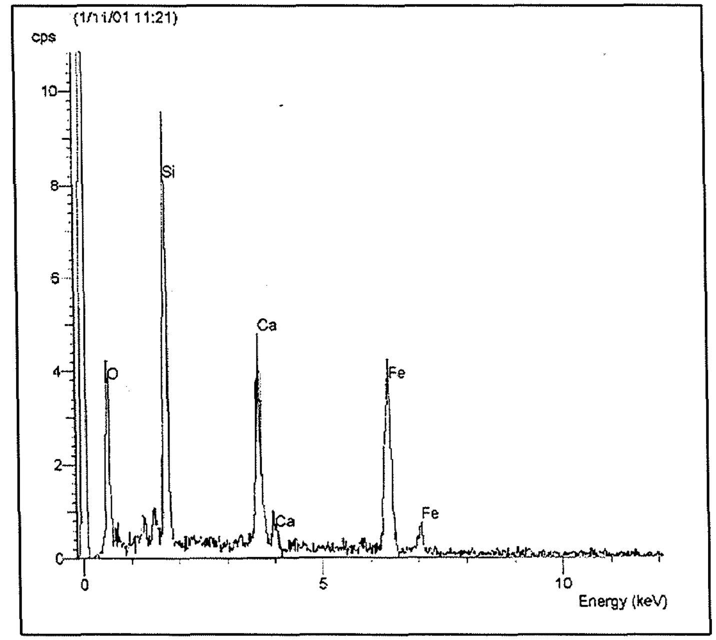
Magnified view of the texture shown on the previous plate. Equant and bladed crystals are composed of pure Fe-arsenide, although EDX spectrum (right) indicates the presence of calcium, likely calcite, in the more anhedral texture at left. Scale bar = 2 µm. (1125×).

EDX spectrum of massive texture shown at left. In addition to Fe and As, the spectrum includes well-defined Ca peaks, indicating calcite admixed with arsenide(s).

PLATE 4
Sample SS SIN 10

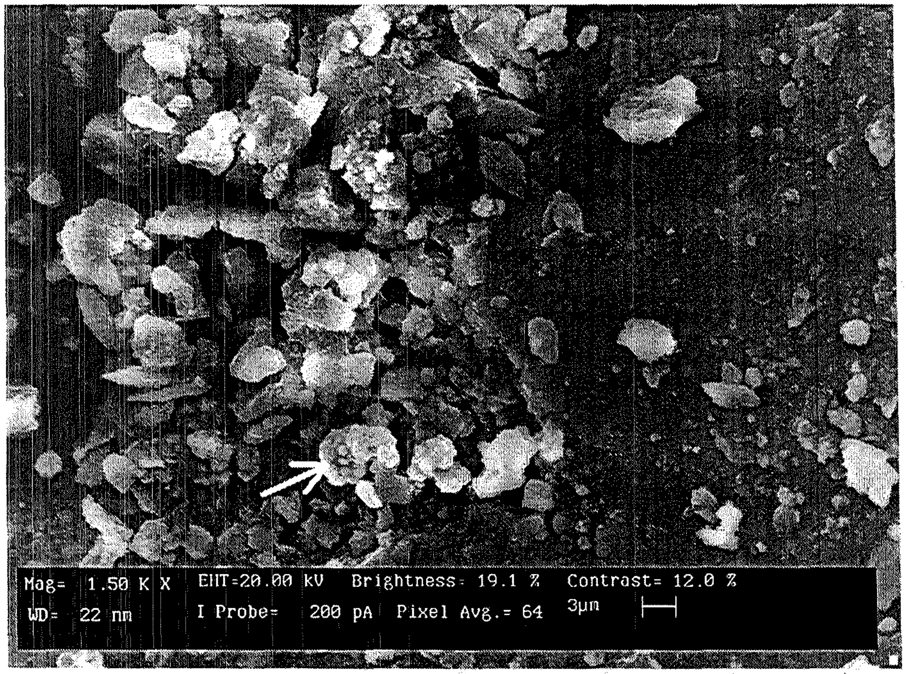


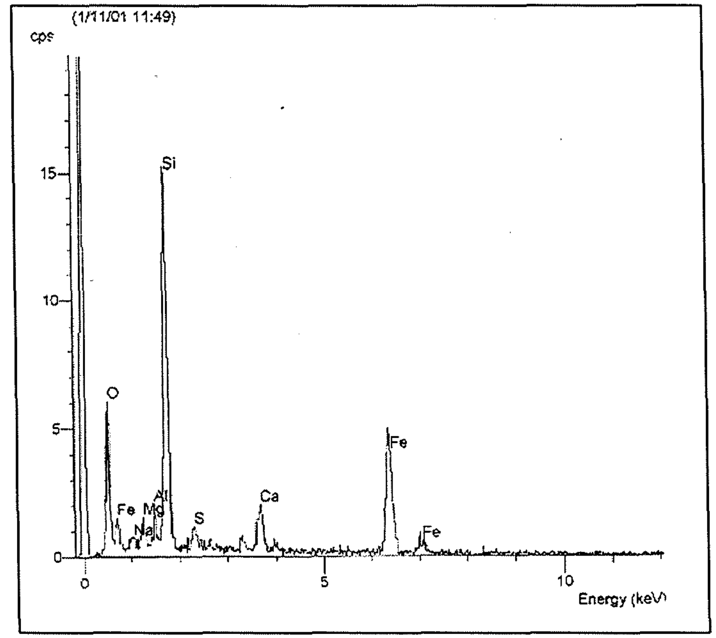
Textural overview of a glassy fragment. Microcrystalline glass in the background is overgrown by a thin, discontinuous crust of calcite, visible here as well crystalline euhedral rhombs. Scale bar = 10 µm. (225×)



EDX spectrum illustrates elemental composition of the entire view at left. Glass composition is rich in Fe, and well-defined Ca peaks clearly indicate calcite. Trace Al and Mg are also visible between Si and O.

PLATE 5
Sample SS SIN 10

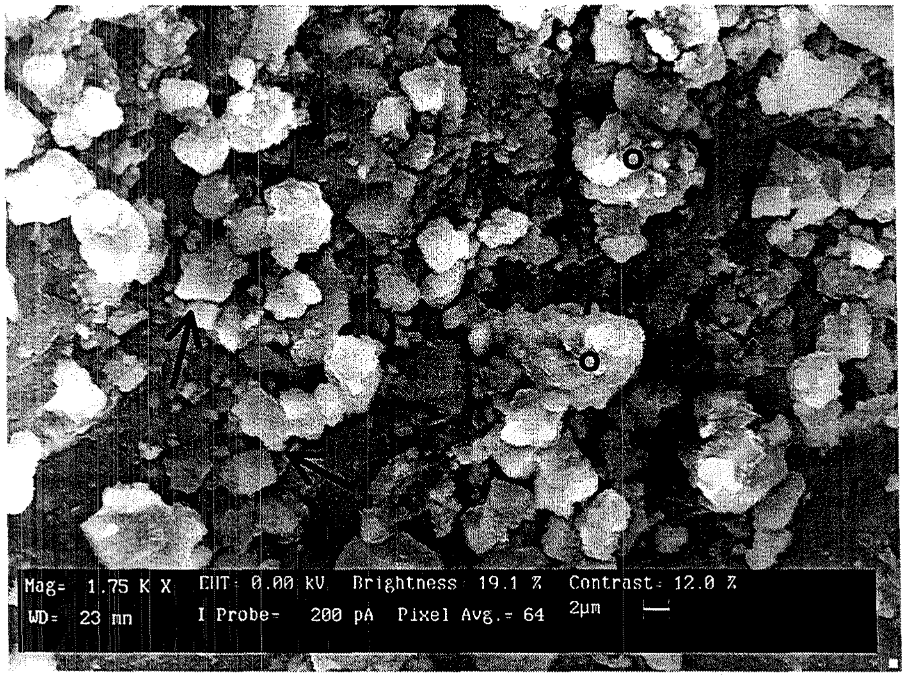




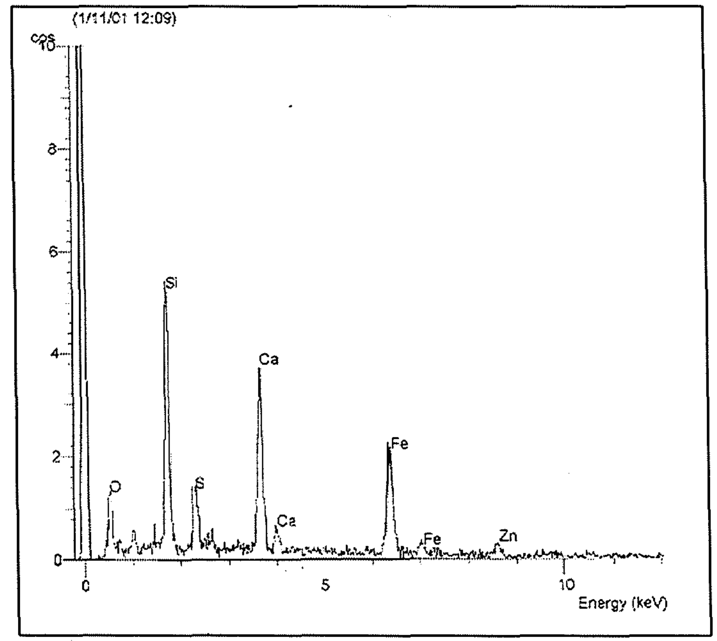
Textural detail illustrates admixed opaline silica and calcite. Siliceous particles typically form anhedral spherules (**arrow**), and calcite forms microcrystalline rhombs. Dense, massive texture at right is nearly pure siliceous glass. Scale bar = 3 µm. 1500×

EDX spectrum corresponds to the image at left. Fe-bearing glass also contains calcite, and a possible sulfate. Traces of Al and Na may indicate incipient alteration to clay.

PLATE 6
Sample SS SIN 10

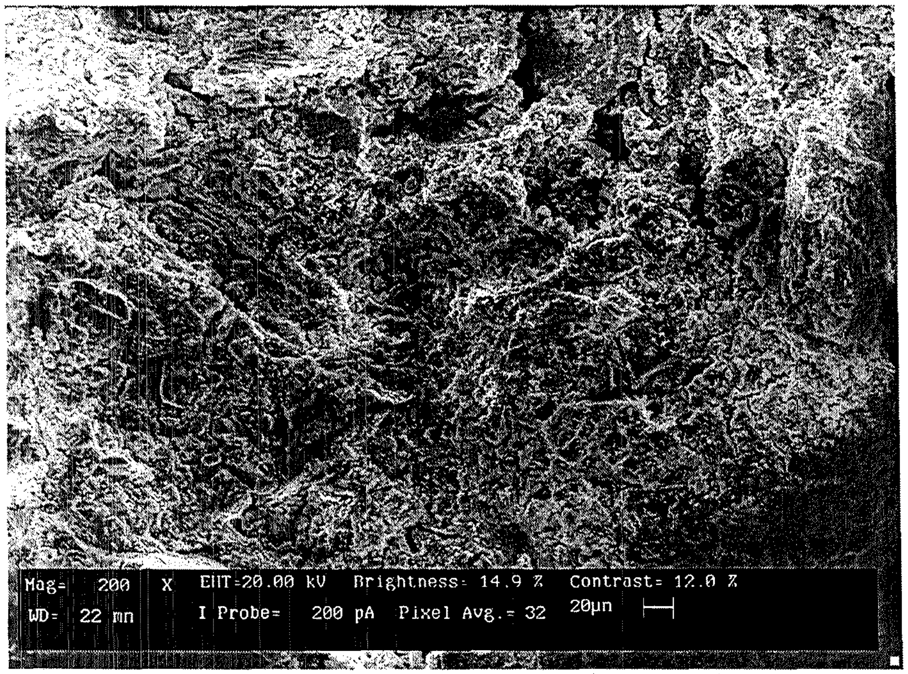


More magnified view of microcrystalline texture. Opaline spherules (**o**) are commonly intermixed with calcite rhombs (**arrows**). Corresponding EDX spectrum is shown at right. Scale bar = 2 µm. (788×)

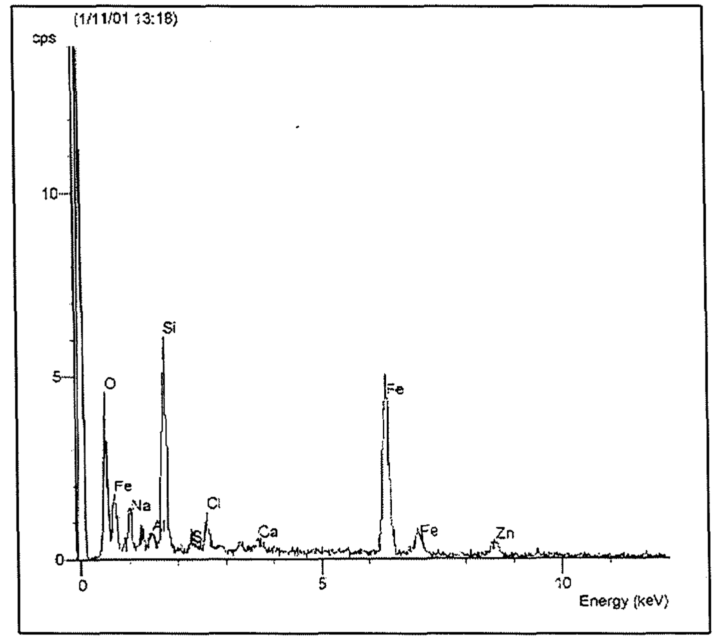


EDX spectrum reveals well-defined peaks for Si, O, Fe, and Ca, corresponding to the Fe-rich siliceous glass and calcite. The presence of S and possible Zn suggests intermixed sphalerite.

PLATE 7
Sample SS SIN 11

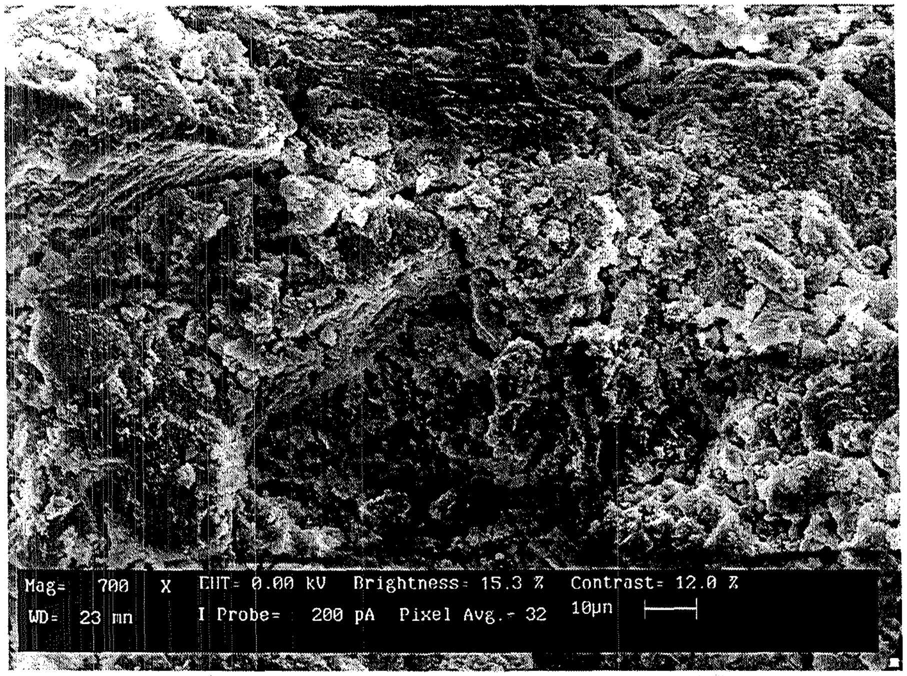


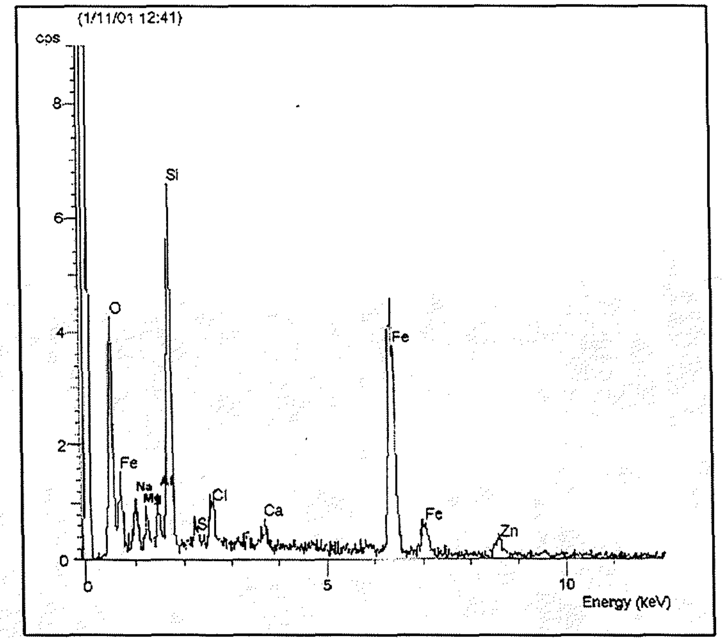
This friable, porous scale sample contrasts with dense, glassy material in samples Sin 10 and EL 12. Massive, loosely crystalline material is largely composed of glass, although contains a higher proportion of Fe. Scale bar = 20 μm. (90×)



EDX spectrum corresponds to the image at left. An unusually high proportion of O and Fe, with respect to Si, indicates the presence of Fe-oxides. The brown color and friable nature of the sample also confirms Fe-oxides. Small peaks for Na, Al, S, Cl, Ca, and Zn suggest that other trace minerals exist, including possible clay (nontronite?) and sphalerite.

PLATE 8
Sample SS SIN 11

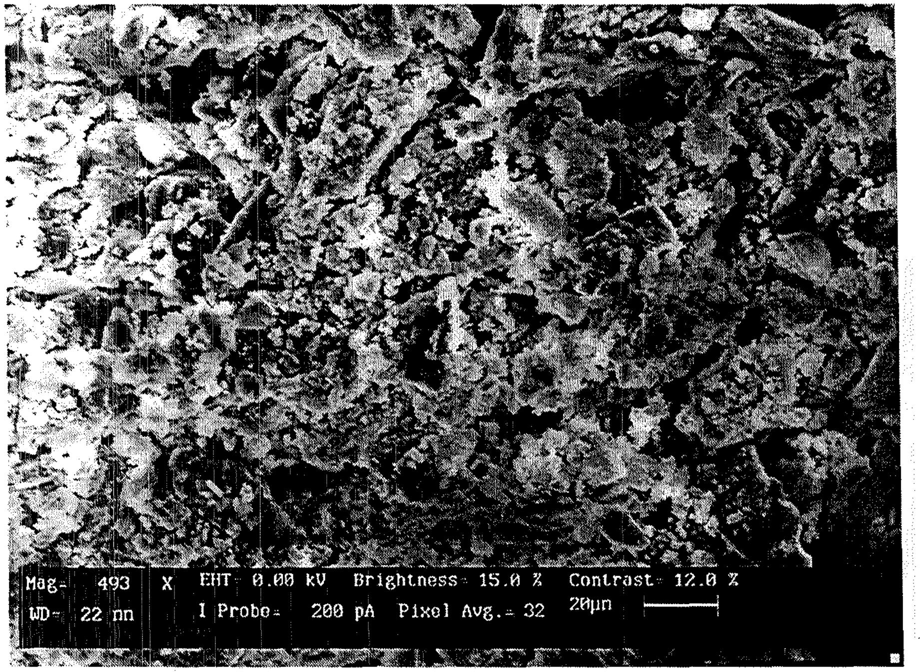




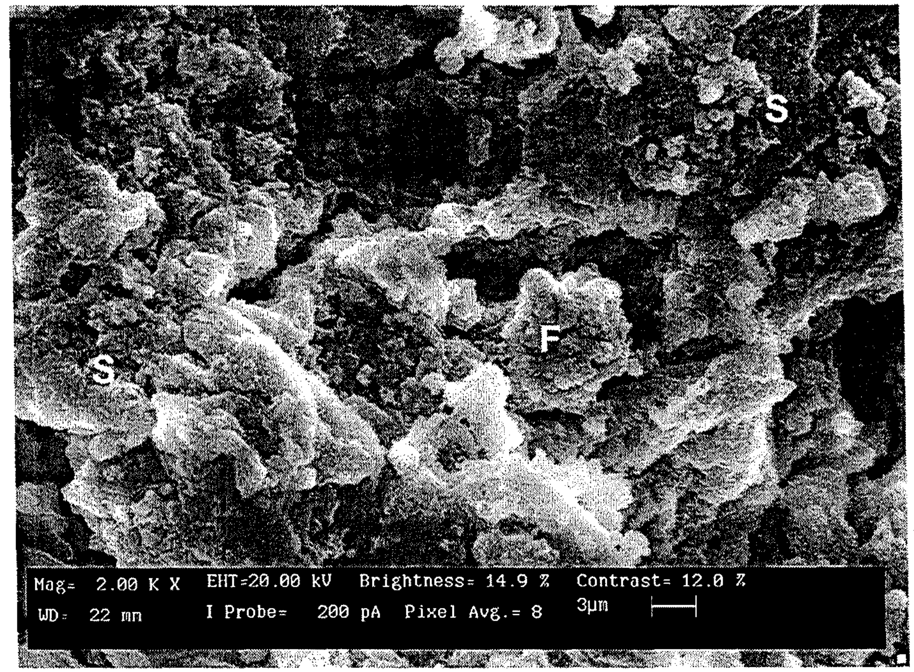
Low- to medium-magnification view of friable, porous texture. Loosely packed, poorly crystalline material includes opal, Fe-oxides, and trace clay. Diverse elemental composition shown at right indicates the presence of other trace minerals (calcite, sphalerite) as well.

EDX spectrum corresponds to the image at left. Anomalously high Fe peak reflects the abundance of Fe-oxide minerals admixed with silica/glass. Minor elemental peaks for Na, Mg, Al, S, Cl, Ca, and Zn may represent clay alteration and trace sulfides.

PLATE 9
Sample SS SIN 11

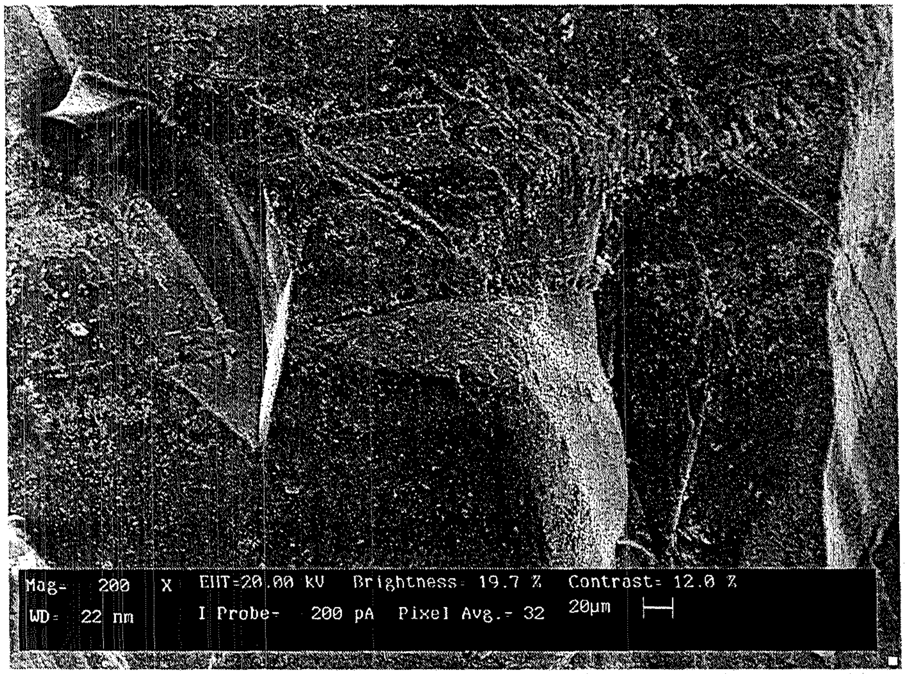


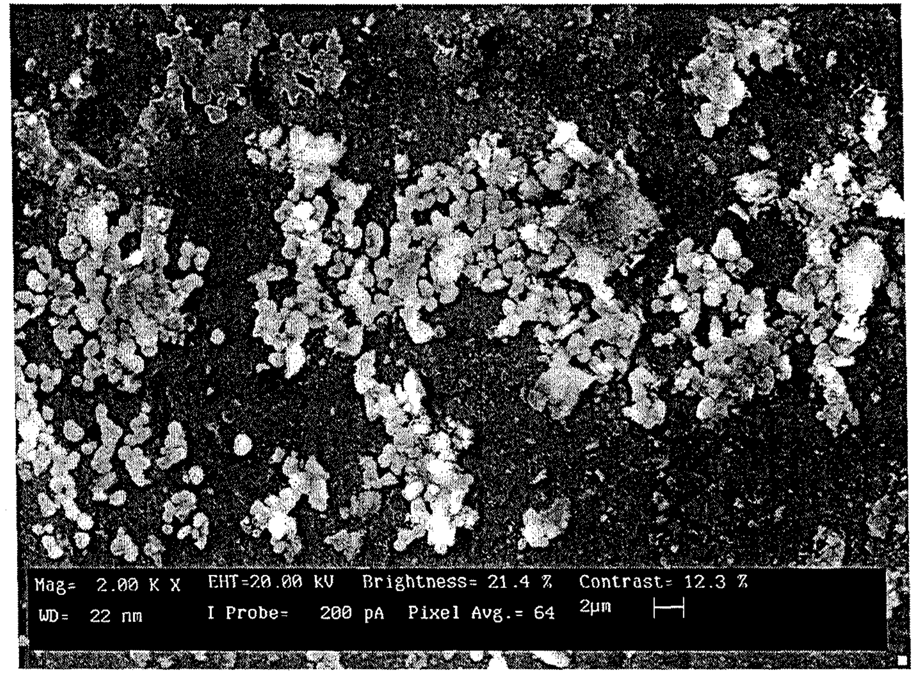
Another view of porous, poorly crystalline texture. Most of the visible particles are fragments of Fe-rich opal and Fe-oxides, although highly conductive flakes could be replacive clays. Major elemental peaks collected from this image are Si, O, Fe, and Ca. Scale bar = 20 µm. (222×)



Textural detail of poorly crystalline matrix. Spot EDX analysis throughout this image indicates the presence of Fe-oxide spherules (**F**) and slightly altered Fe-rich glass (**S**). Siliceous areas contain minor peaks for Na, Al, Cl, S, and Zn. Scale bar = 3 µm. (900×)

PLATE 10
Sample SS EL 12

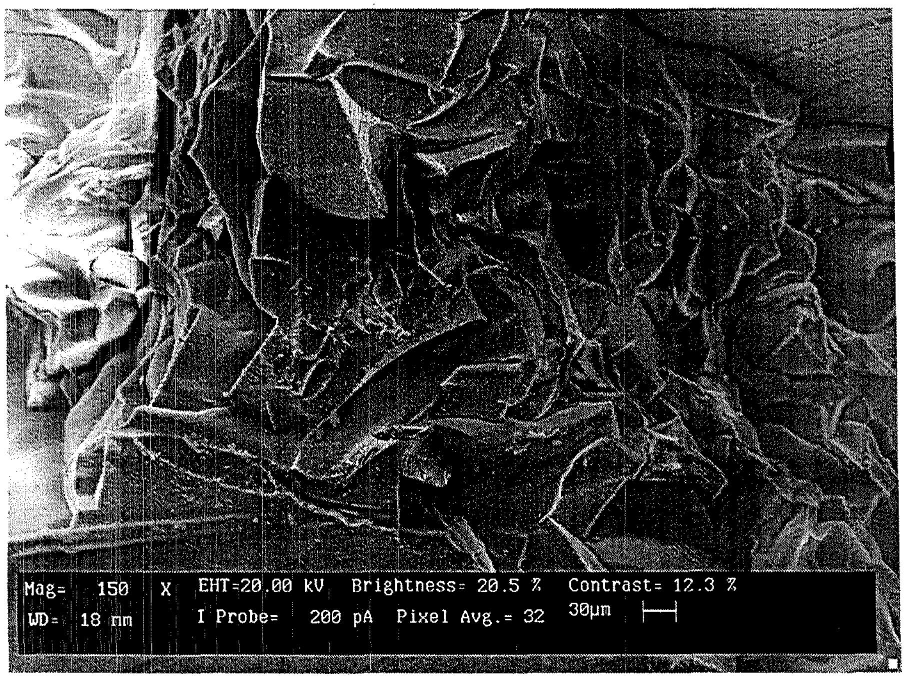


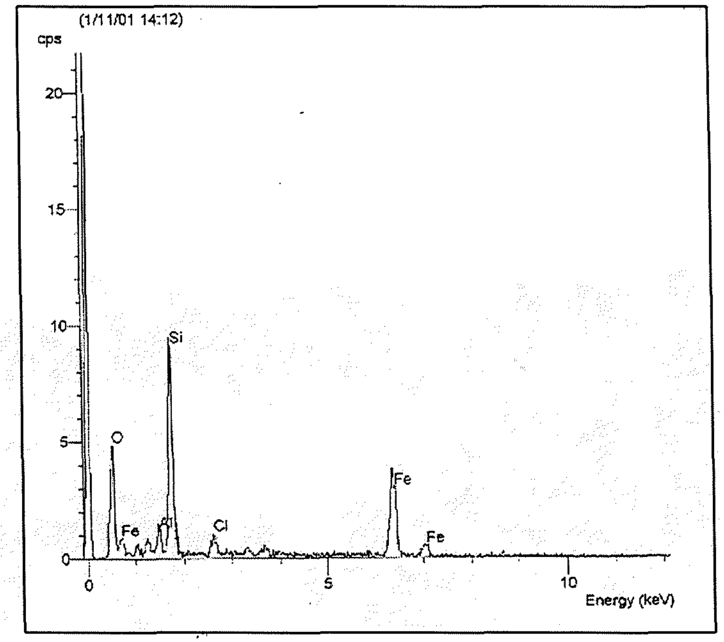


Low-magnification overview of a concoidally fractured glass fragment. Material surface is comparatively smooth and EDX composition indicates three prominent peaks: Si, Fe, and O. Scale bar = 20 μm. (90×)

Higher-magnification detail of the glass surface shown at left. Microcrystalline particles on the fracture surface are also composed of silica, but contain slightly less Fe, according to concurrent EDX analysis. Scale bar = 2 μm. (900×)

PLATE 11
Sample SS EL 12





Another view of unaltered glass exhibiting concoidal fracture and uniform composition and texture. Corresponding EDX spectrum is highlighted at right. Scale bar = 30 μm. (68×)

Glass sample at is largely composed of a Fe-bearing glass. Minor peaks for Al, Cl, and possible Mg are also recognized and may be present in the glass. No clay alteration is visible at left.

EL-12clayoxide
↑
from EG13.xl

Table 2.

Probe analyses of nontronitic clay (calculated as oxides)

sample	El-12a	El-12b	El-12c
SiO2	43.53829	44.35225	43.28339
TiO2	0	0.060048	0.005004
Al2O3	3.543764	3.522985	3.339752
Fe2O3	36.05641	35.83966	33.92597
MnO	0.001291	0	0
MgO	4.296561	4.266339	4.639077
CaO	0.705096	0.706495	0.664525
Na2O	1.183544	0.798016	1.201068
K2O	1.15439	1.19777	1.088115
ZnO	0.080925	0.133215	0
Subtotal	90.56027	90.87678	88.1469
Cl	0.484	0.558	0.37

SINC-10

Dec 6, 2000 ④.

setu egil.

Coming up with Ca + Fe + Mn
white band -
carbonate ~ siderite
(burns like a carbonate)

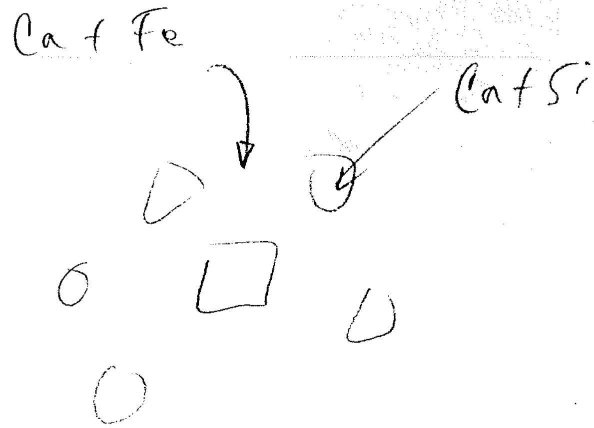
only small areas with Si -
TAP PET LIF
egi_7. Si - S - Fe

Zn = S sphalerite ?

egi_7. Zn - Ca - Mn

dark area - different fragment - porous

x y
-13000 and +1000



Ca + Fe + Si + Mn
TAP PET LIF
egi 8. Si - Ca - Fe
egi_8. As - Cl - Mn

-Shell 1s -1rt egi*

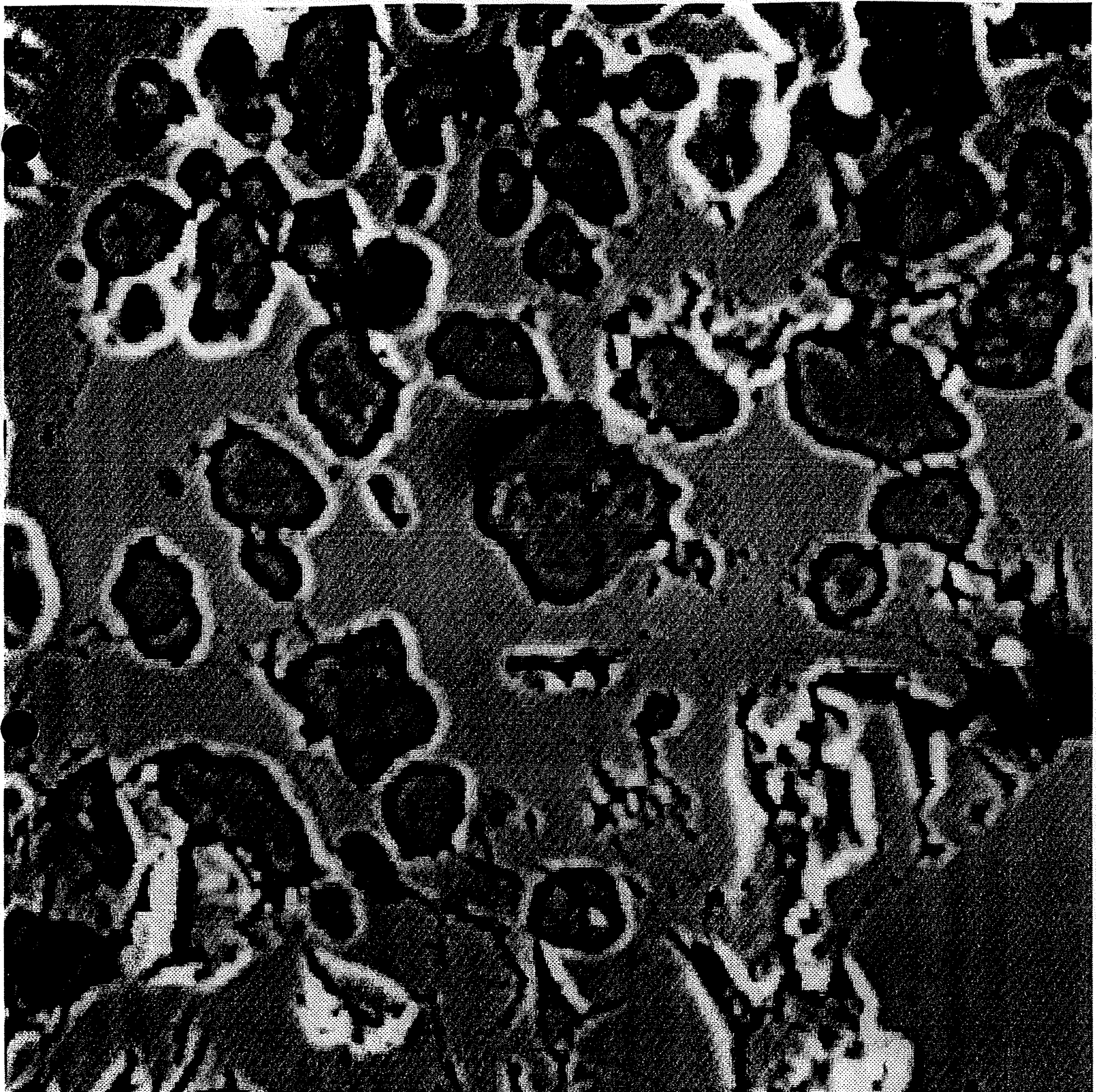
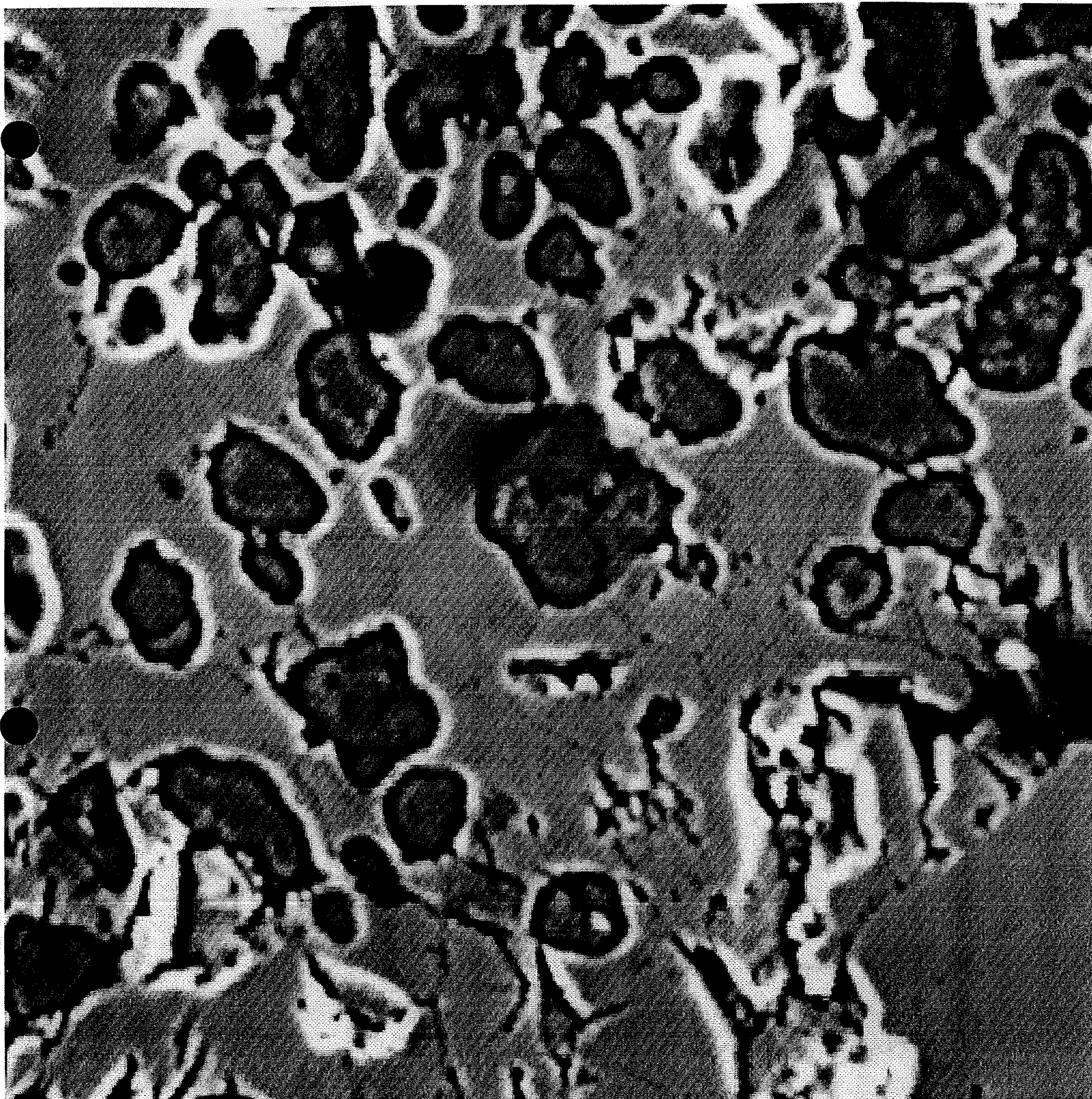


fig_8asclnmisk.tif

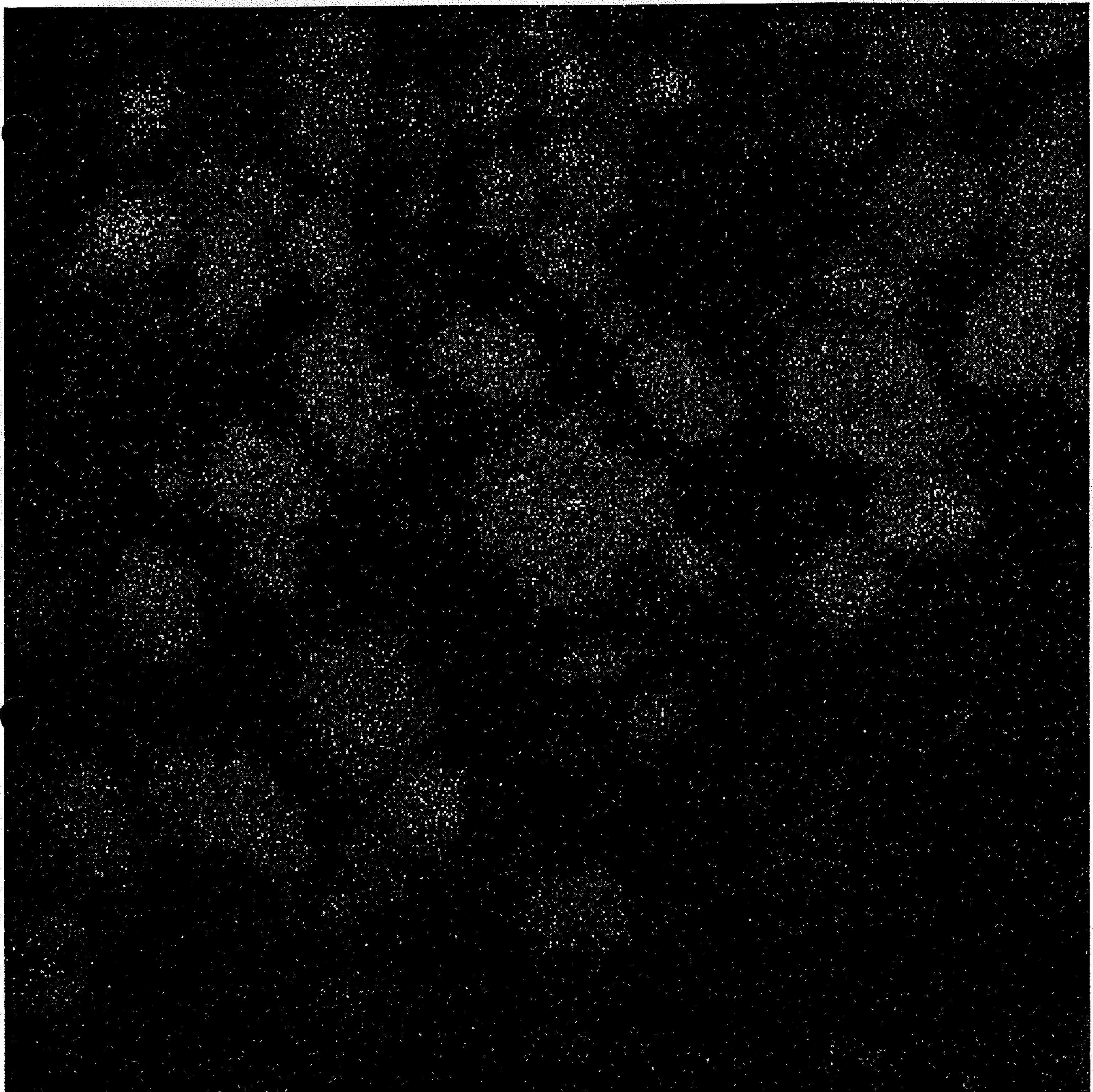


Dec 66. [illegible]
Sinc-10
[illegible]

egi_8asclmnrsB.tiff

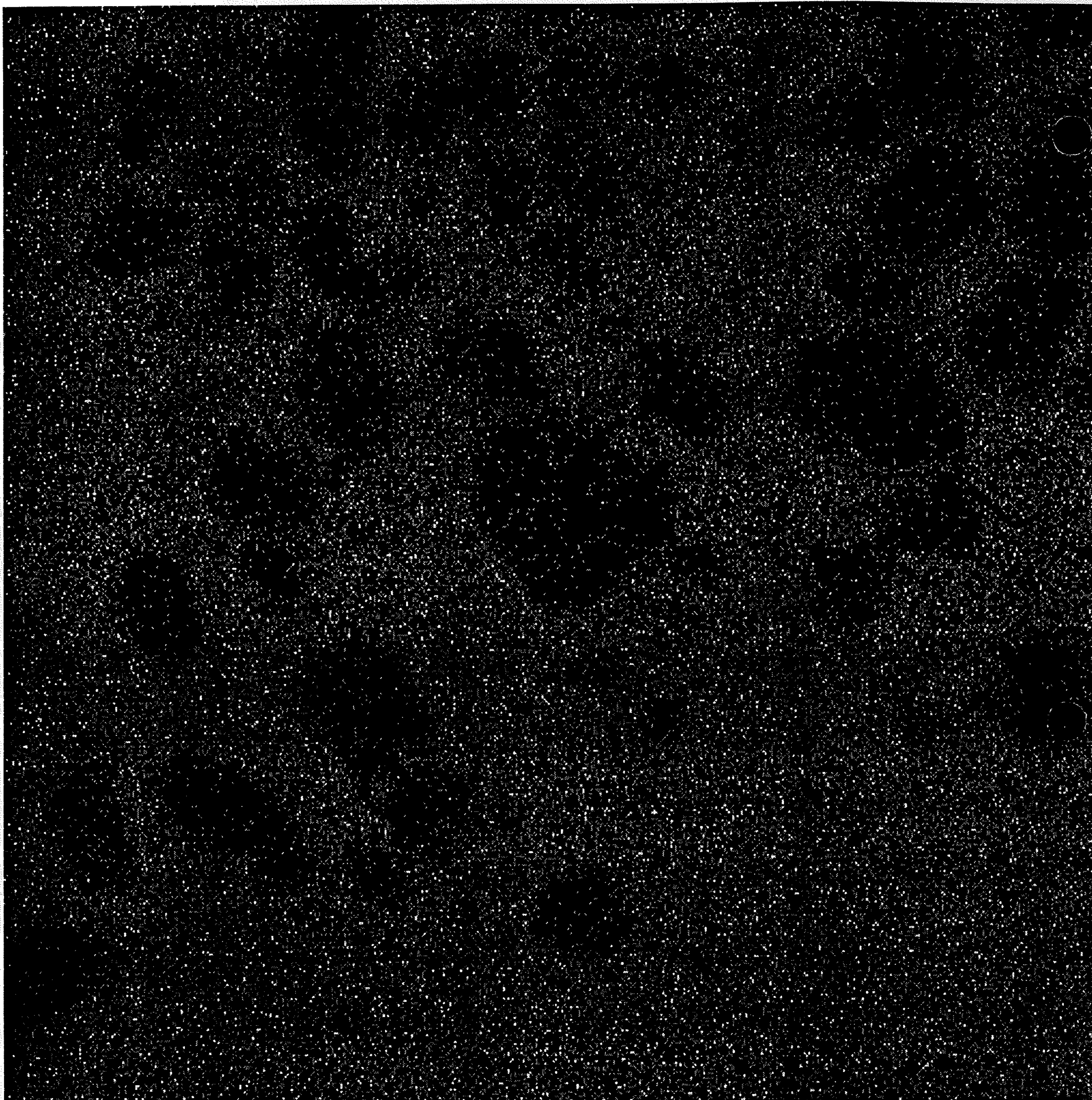
As

egi-8 aselmap1.tif



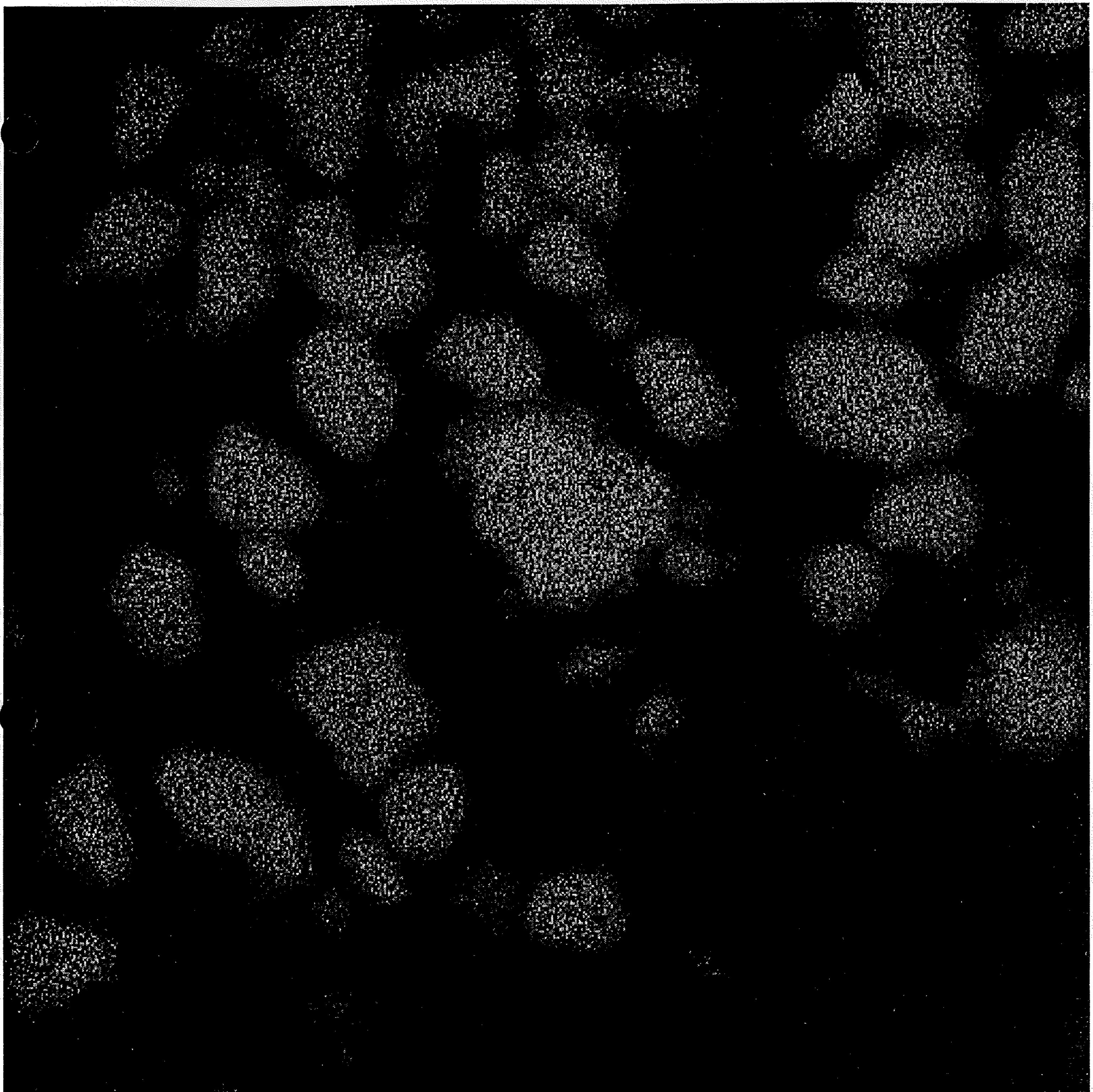
ce

egi_8aselmn5P3.tiff



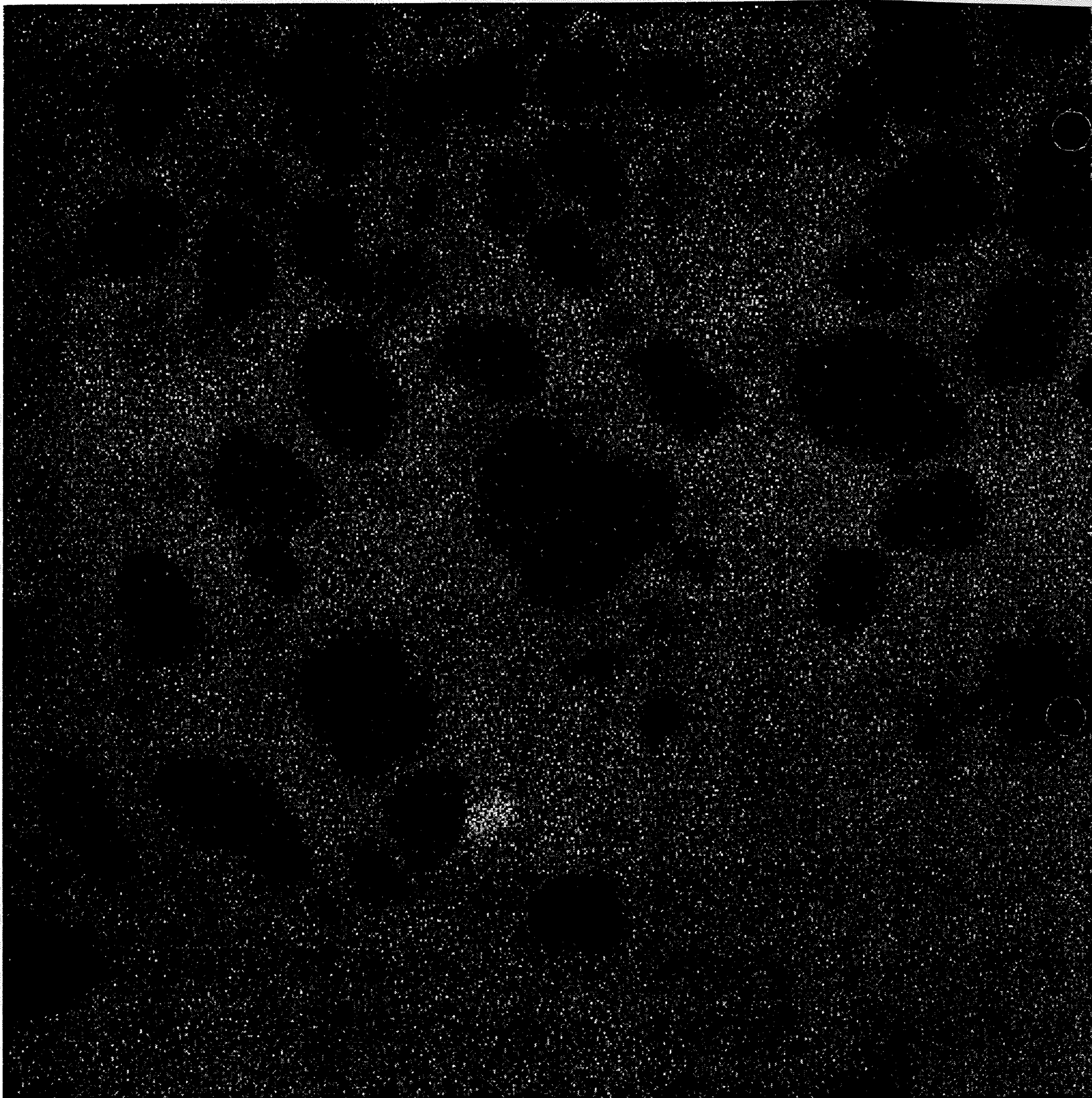
Mn

egi_8 asclmn SPY.tiff



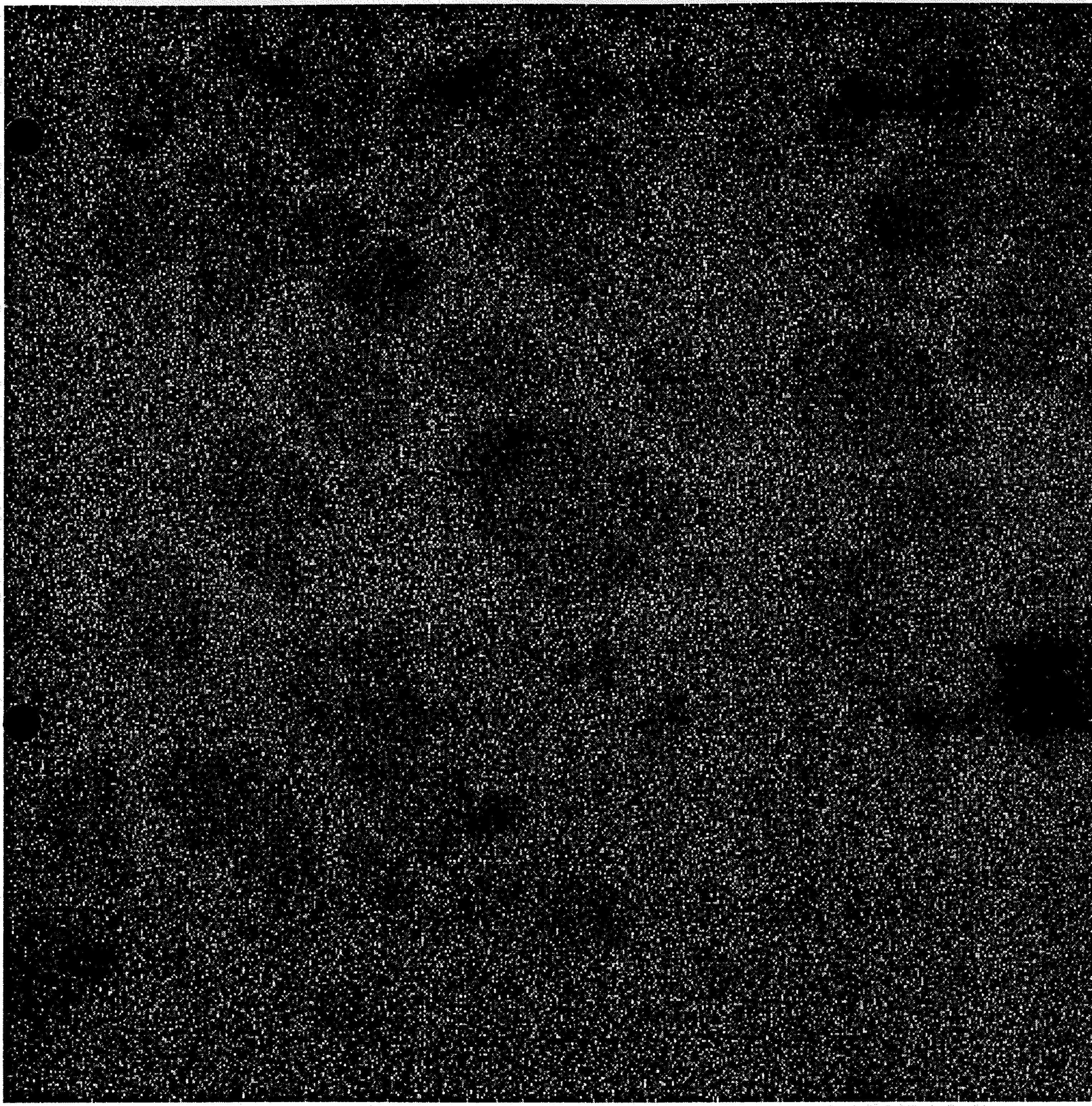
Si

egi_8 sicafe SP1.tiff



Ca

egi_8sicalesP3.tiff



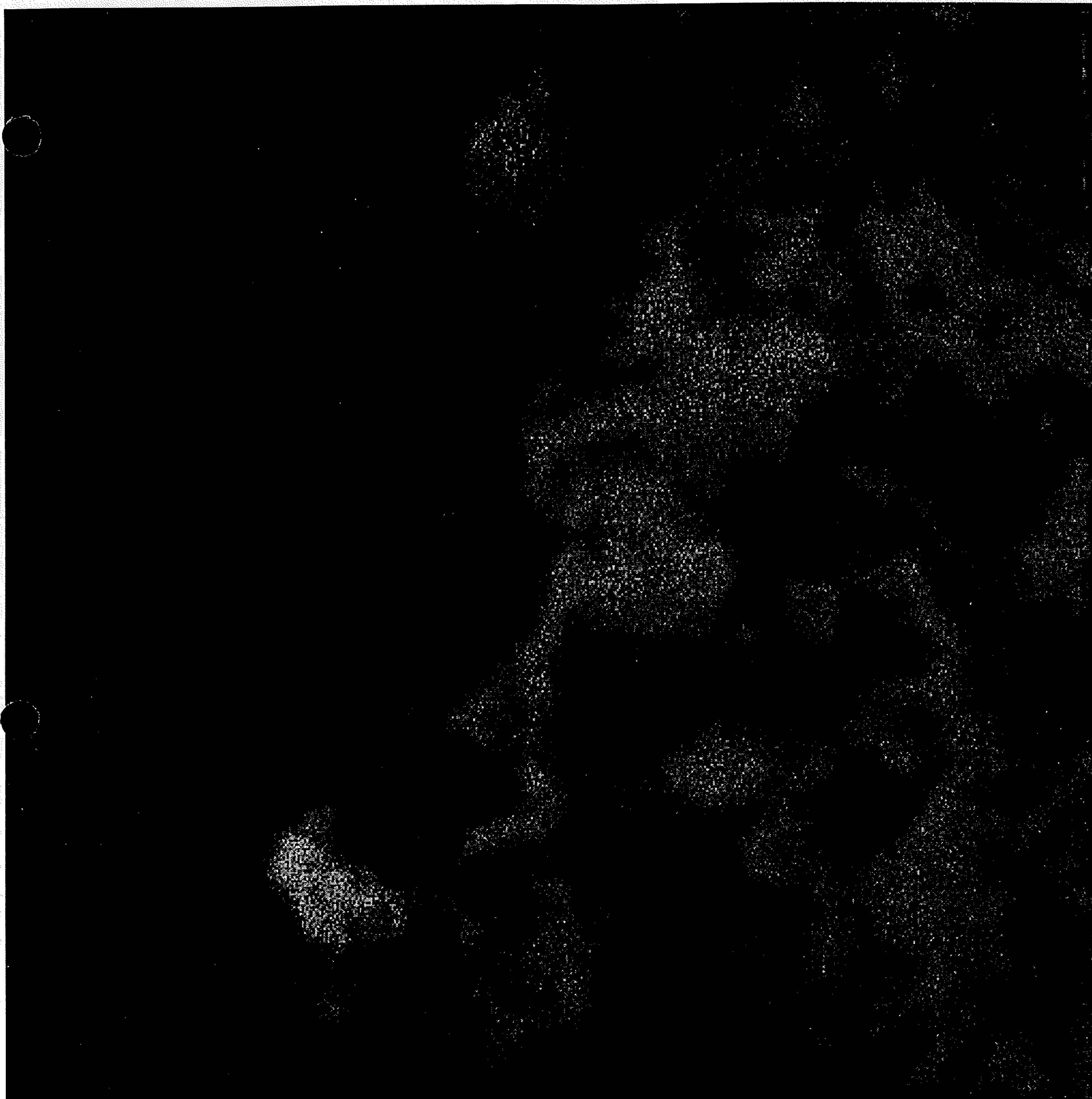
Fe

fgi_8sicale SP4.tiff

Dec. 06, 2000

Sinc - 10
production scale

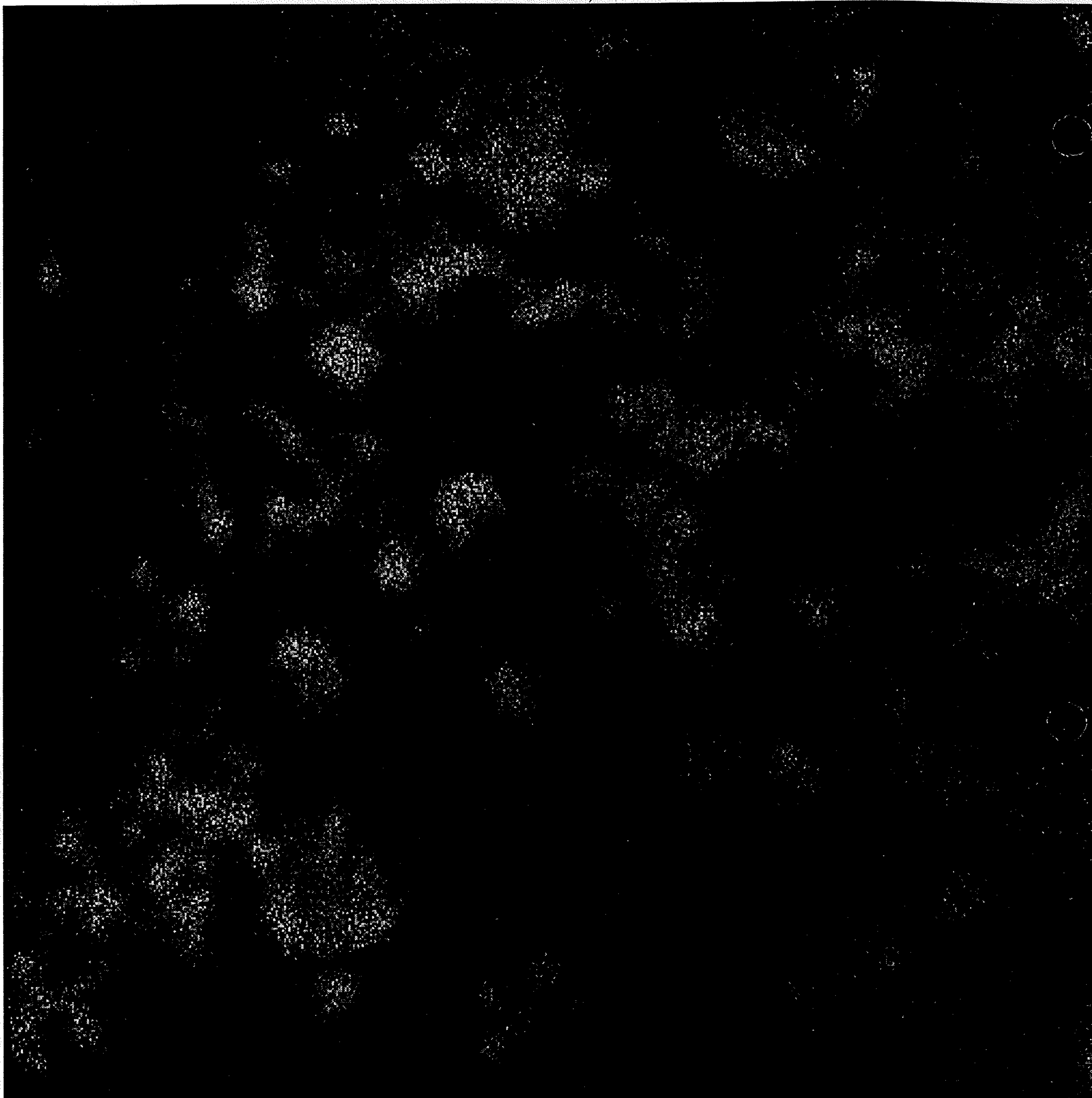
sgi - = sisteABS.tiff



Si

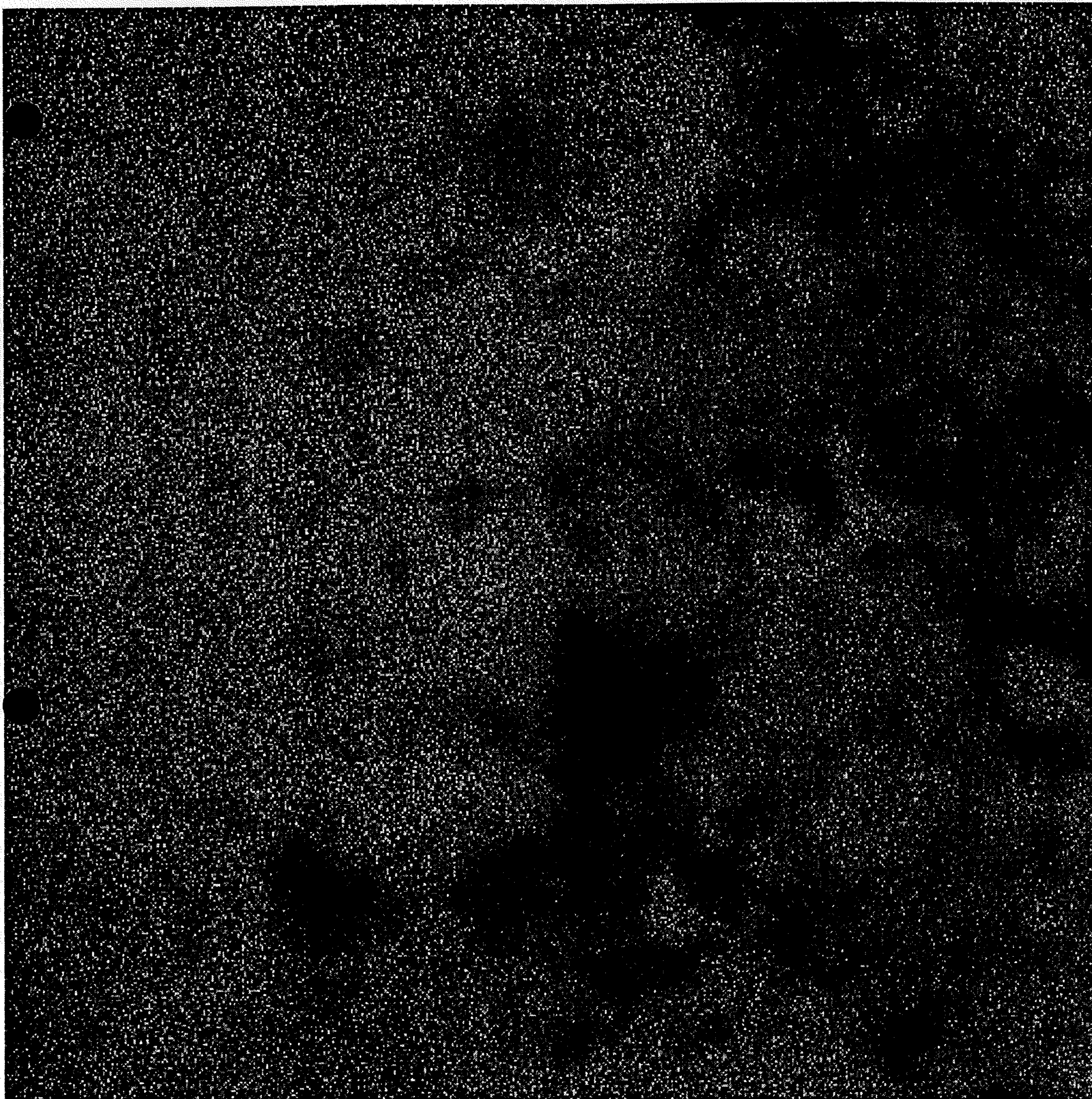
egi_7siSfe SP1.tiff

ZnS



ZnS

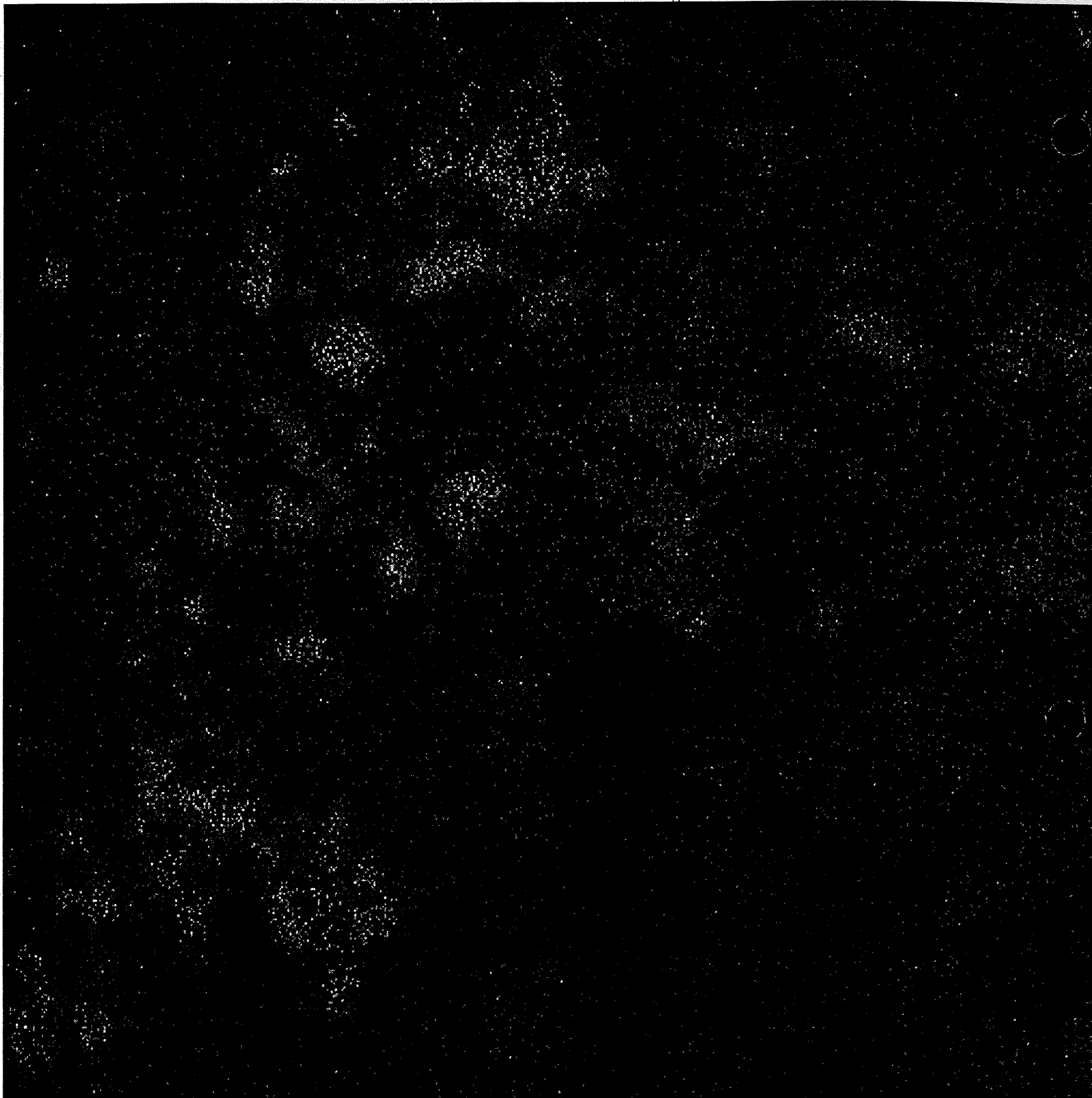
S



Fe

cgi_7si5n.5M.tiff

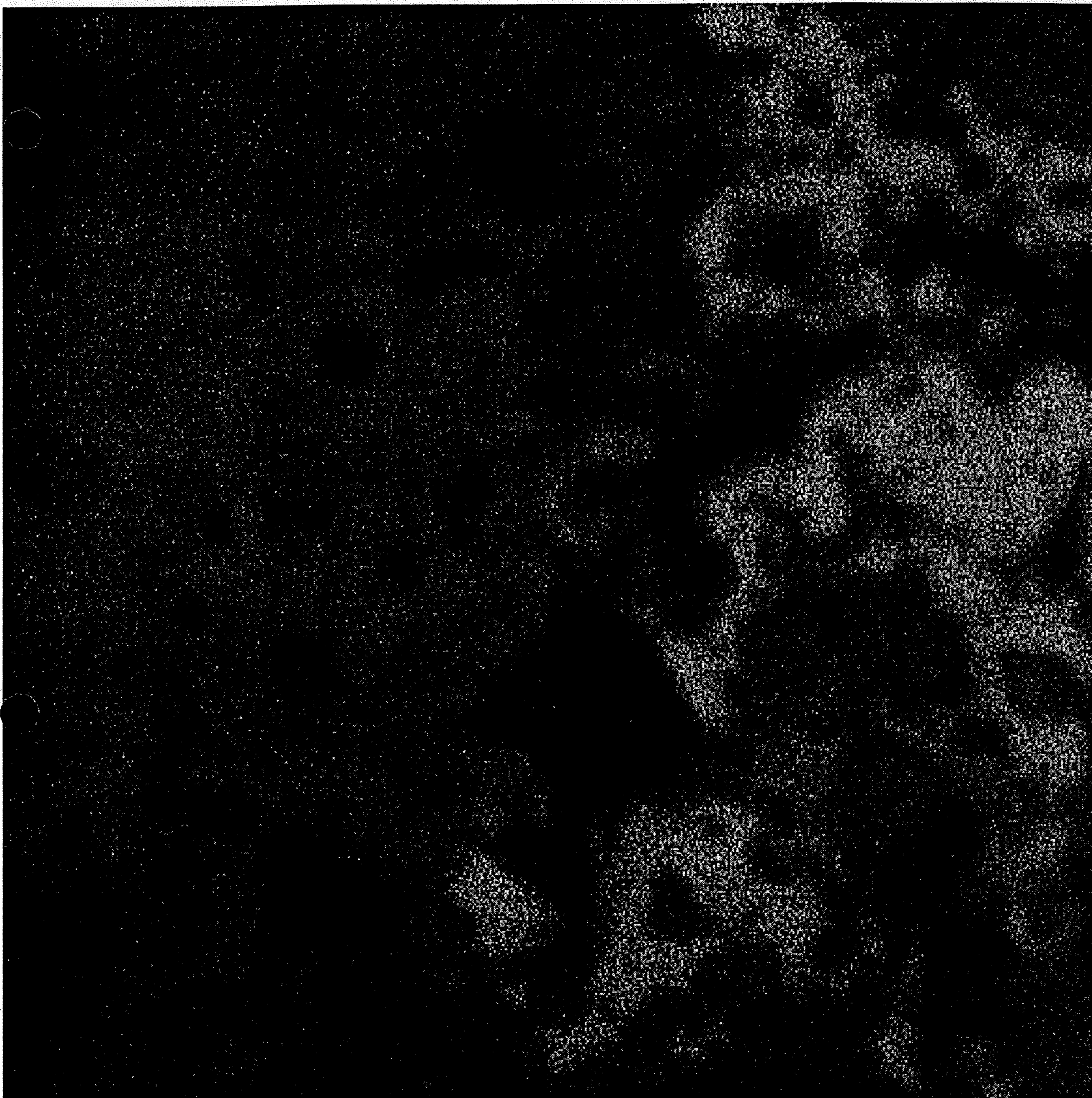
/ ZnS



Zn

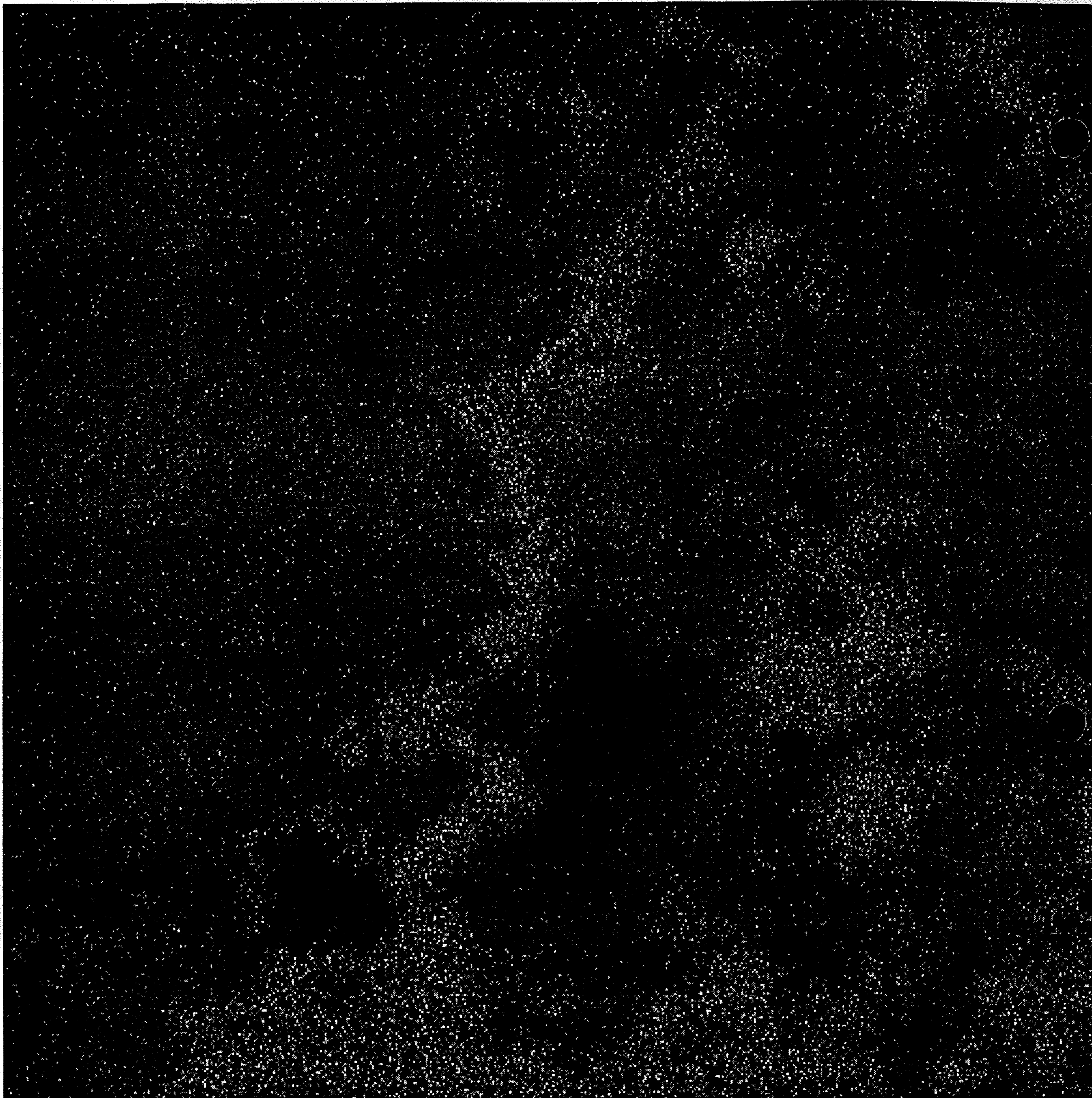
ZnS

egi_7zncamnnS41.tiff



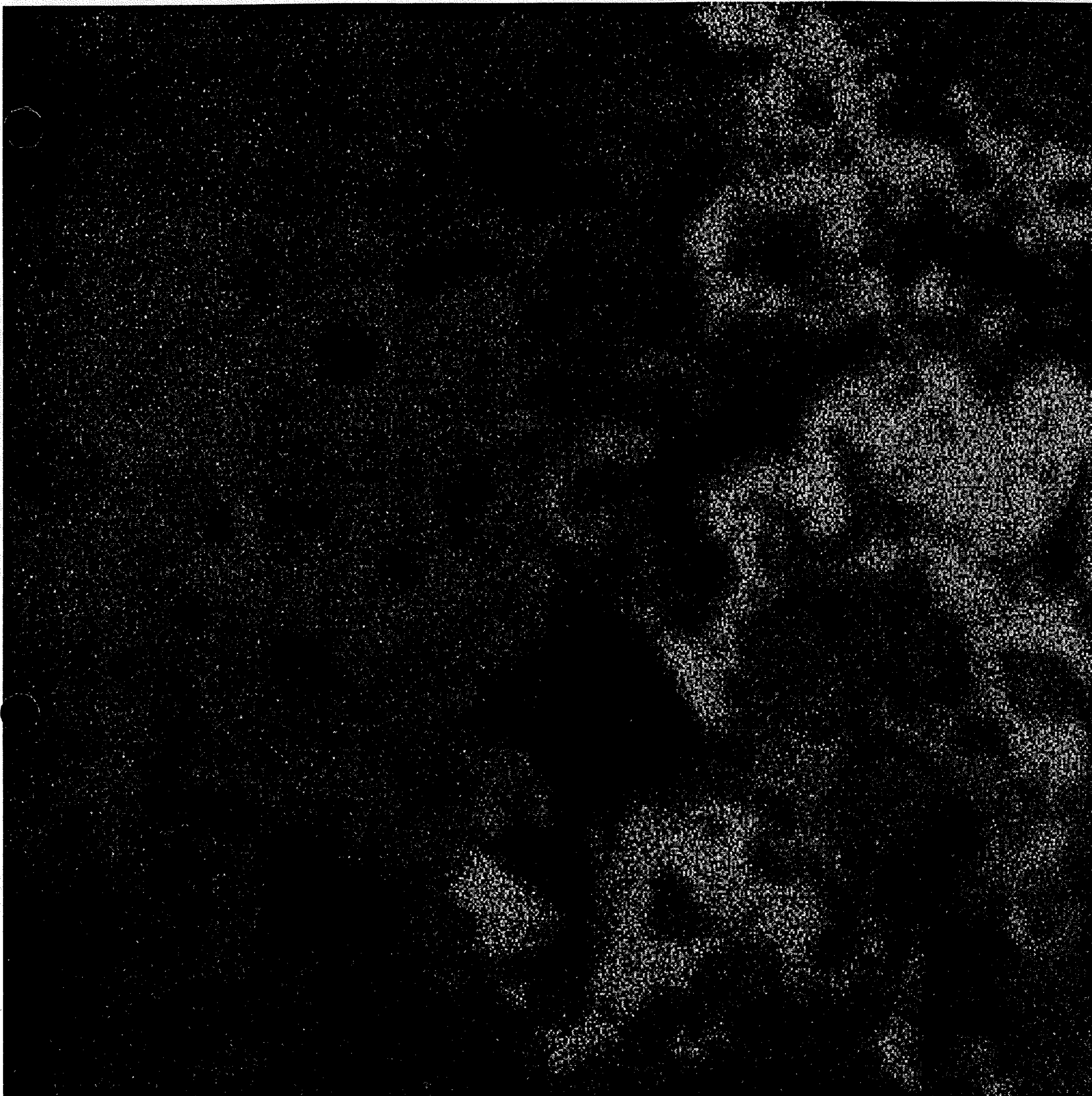
Ca

egi-7 ZnCa111aSP3.tiff



Mn

egi_7211camn 514.tiff



Ca

egi-7 ZnCallInSP3.tiff

~~detected~~ SEMORE-12 ~~SAR-10~~

X - 18181
28701
Setu

52% - nontronite } Jeff says mostly clay (poorly xlm)
~~[illegible] - [illegible]~~
<10% loellingite

Dec 6, 2000
①

2 different dark areas.

K - Cl - Ca - Si - Fe -

Mg - Si · Fe

Start with garnet declare

TAP	TAP	PET	LIF
Si	~~Al~~	Ca.	Fe
Mg		~~Ti~~	Mn
Al	Na	K.	Ti
		Cl	

add K, Na, Cl   Zn?

Declare filename label: egi 3

stone
writing physics
writing experimental

Analysis - manual

TAP	TAP	PET	LIF
Al	Na	Ca	Ti
	Si	K	Fe
	Mg	Cl	Mn
	Zn		

see libraries

Dec 6, 2000

②

fibrous EL-12

Na - 1.74
Si 19.96.
Al - 1.8
Mg - 2.6.
Zn = .06

Fe - 23.6.
O - 33.

~ 86 wt%.

Now add As -

going to spot that has alot of K, Cl, Ca as well as Si + Fe + Mg
only 41.%
[no comment] hole with clay plucked out?
or with KCl?.?

---

another - Ca + S fibrous small inclusion.
also K + Al
this one only 10%! = hole

---

fibrous -
~~[illegible]~~ = 87%
EL-12 = 87% } without As
a
b 85% with 0% As.

should have 3 analyses of clay

12-6-00
(3)
2:00

EDS on fibrous ~~[illegible]~~ EL-12

Fe - Si - Na - Mg - Zn - As

TAP TAP LIF
Na - Mg - Fe

absorbed - 1000x image   about 80 - 100 μm across per image

egi_5 Na Mg Fe abs.
egi5-5

egi-5
Si - Zn - As

egi-5 Si znas

Back to RR-18   EDS images:
need Cu - S - As - Fe - Ag - Au - Bi

egi-6 As · Ca · Fe

blades of FeAs triangular with calcite in holes - also Cu S in holes.

egi-6. Cu - S - Ni
As
~~didn't show~~, does too.

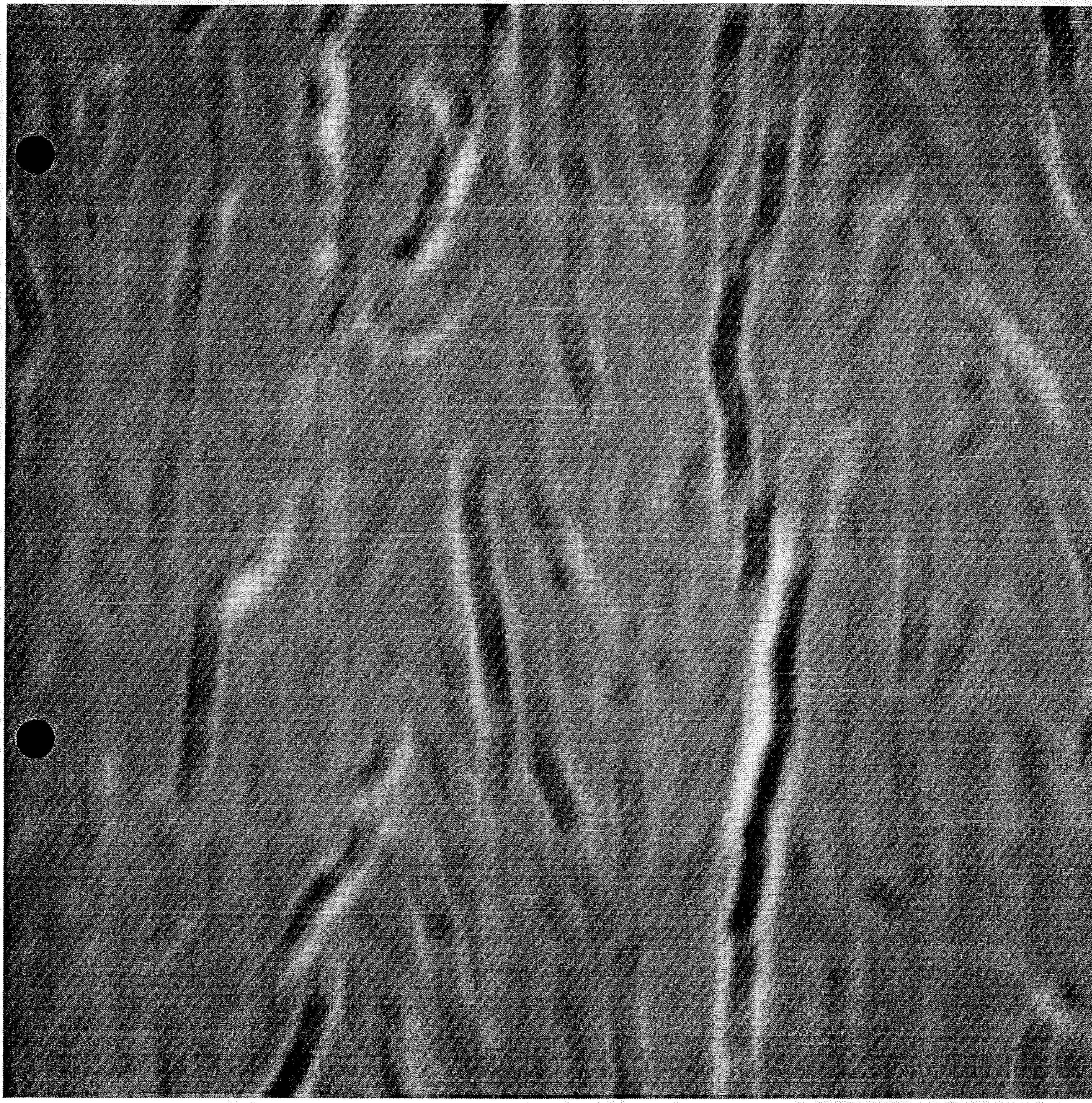
fibrous EC-12 12-6-00

Na	1.74
Si	19.96
Al	1.8
Mg	2.6
Zn	.06
Fe	23.6
O	33

[~83] - 86wt%

$\frac{46}{62}$ = 74%	Na_2O - 62 2 x 23 + 16 =	.74x = 1.74	x = 2.35 Na_2
$\frac{28}{60}$ = 47%	SiO_2 = 60	.47x = 19.96	x = 42.5 SiO_2
$\frac{54}{102}$ = 53%	Al_2O_3 = 102. 2 x 27	.53x = 1.8	x = 3.4
$\frac{24}{40.3}$ = 59%	MgO = 40.3	.59x = 2.6.	x = 4.4
$\frac{65.4}{81.4}$ = 80%	ZnO = 81.4	.80x = .06	x = .75
$\frac{112}{159.7}$ = 70%	Fe_2O_3 = 159.7 2 x 56	.70x = 23.6.	x = 33.7

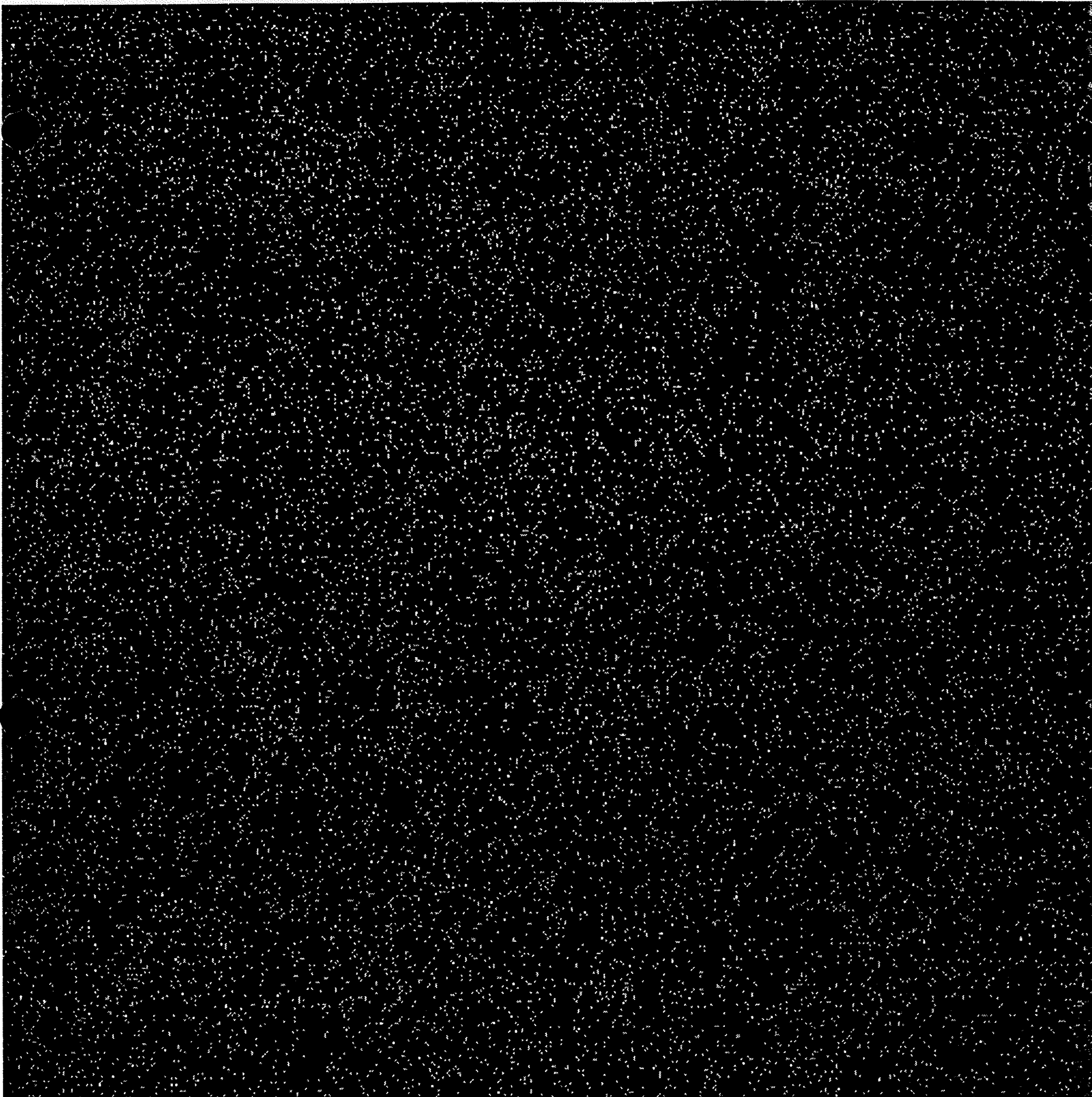
87wt%



Absorbed image
1000x ≈ 100 μm field of view

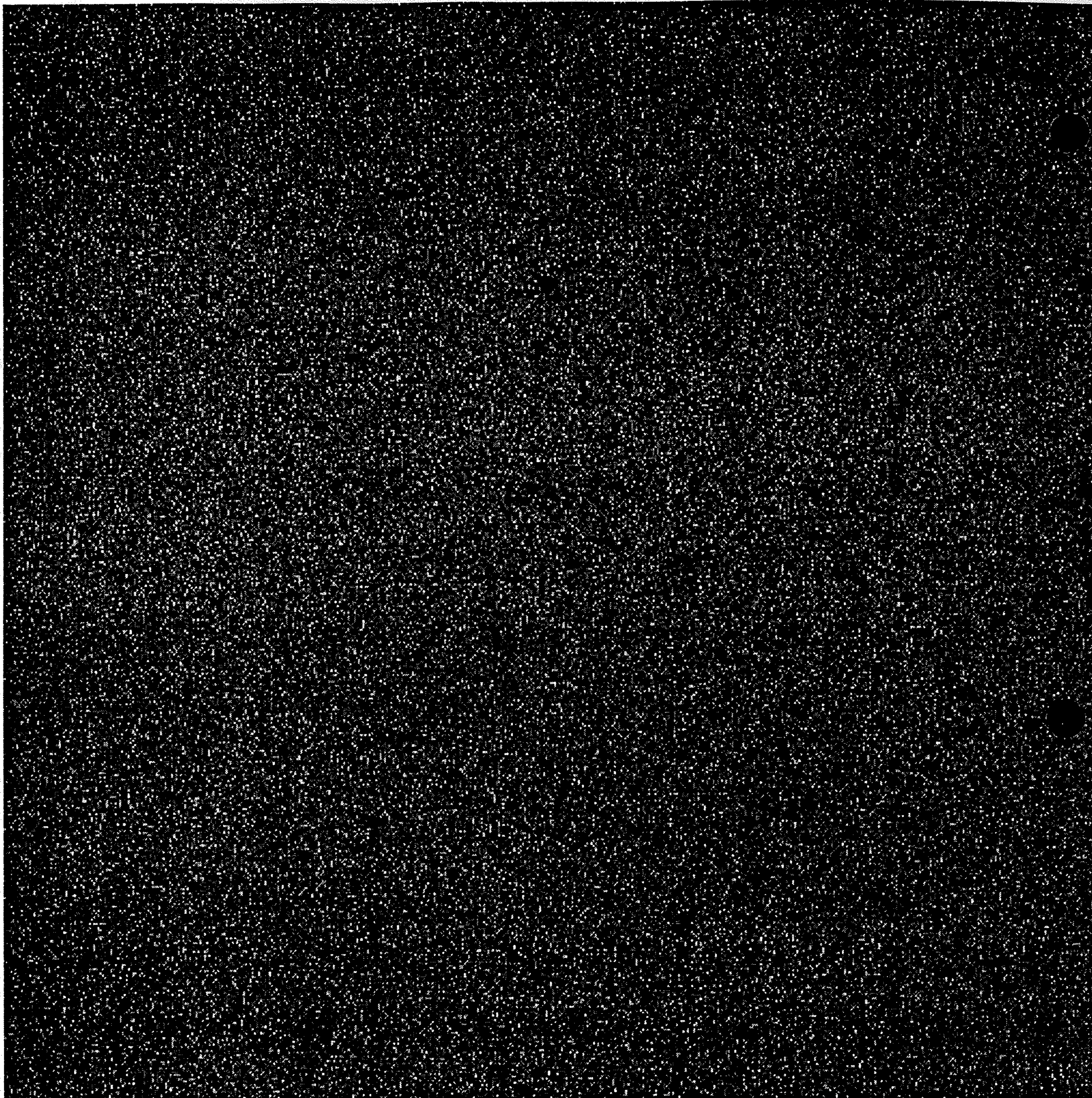
Dec 06 00 –
Elmore - 12
production scale

egi5_namgle ABS. tiff



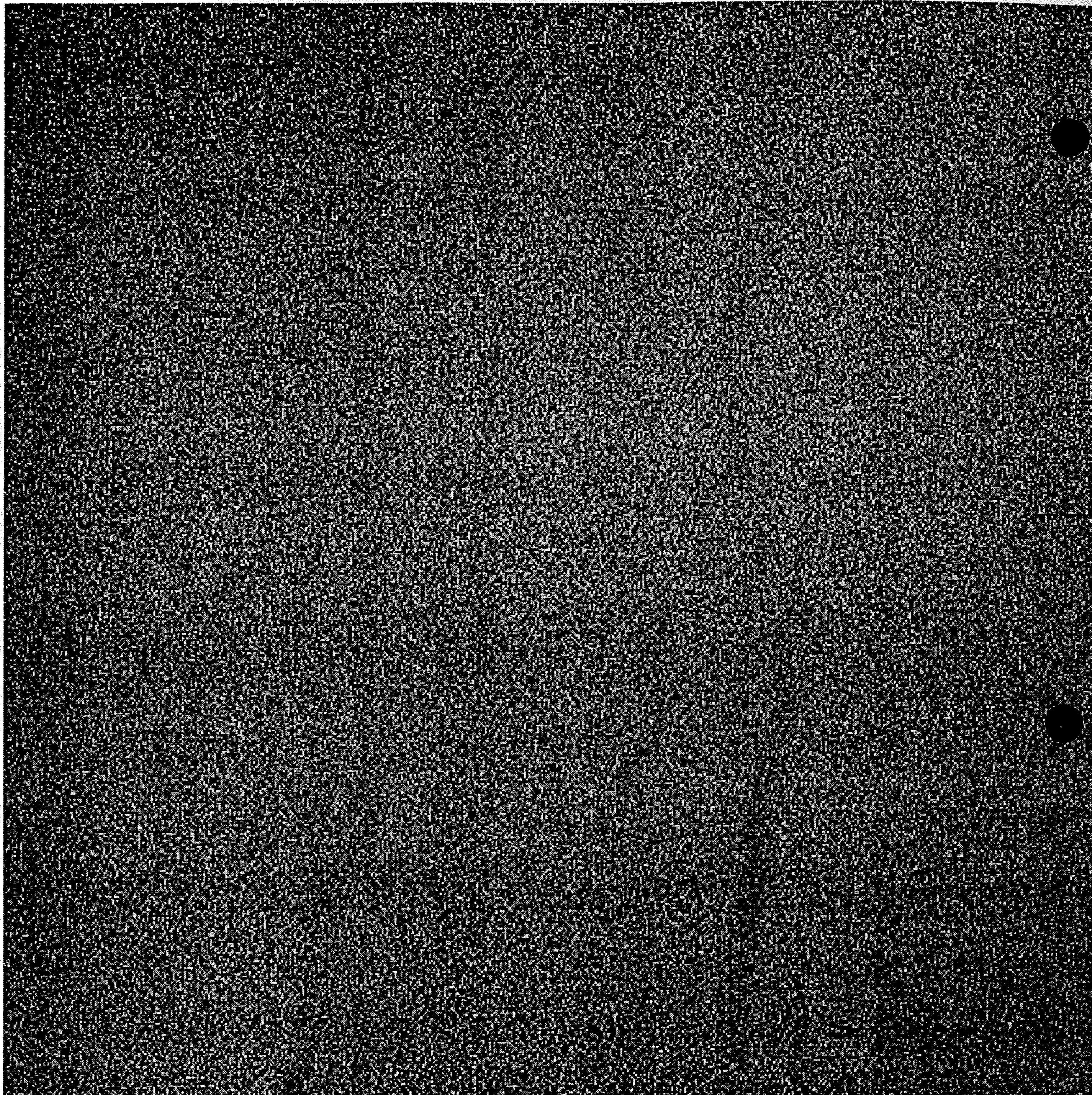
Na

egi5_naangle.SP1.tiff



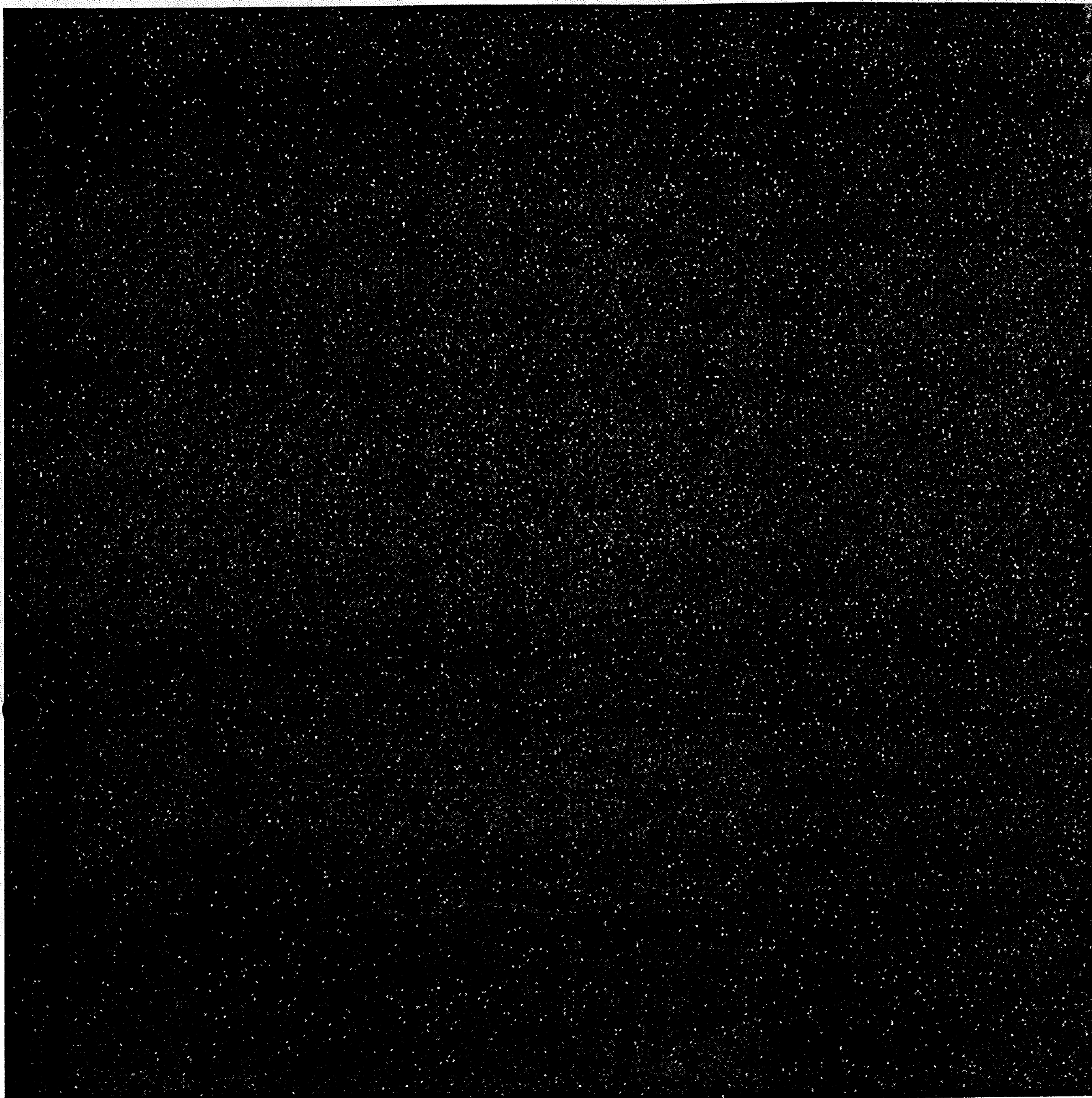
Mg

eg15 – namgfesi2.tiff



Si

egi5_siznas SPl. tiff

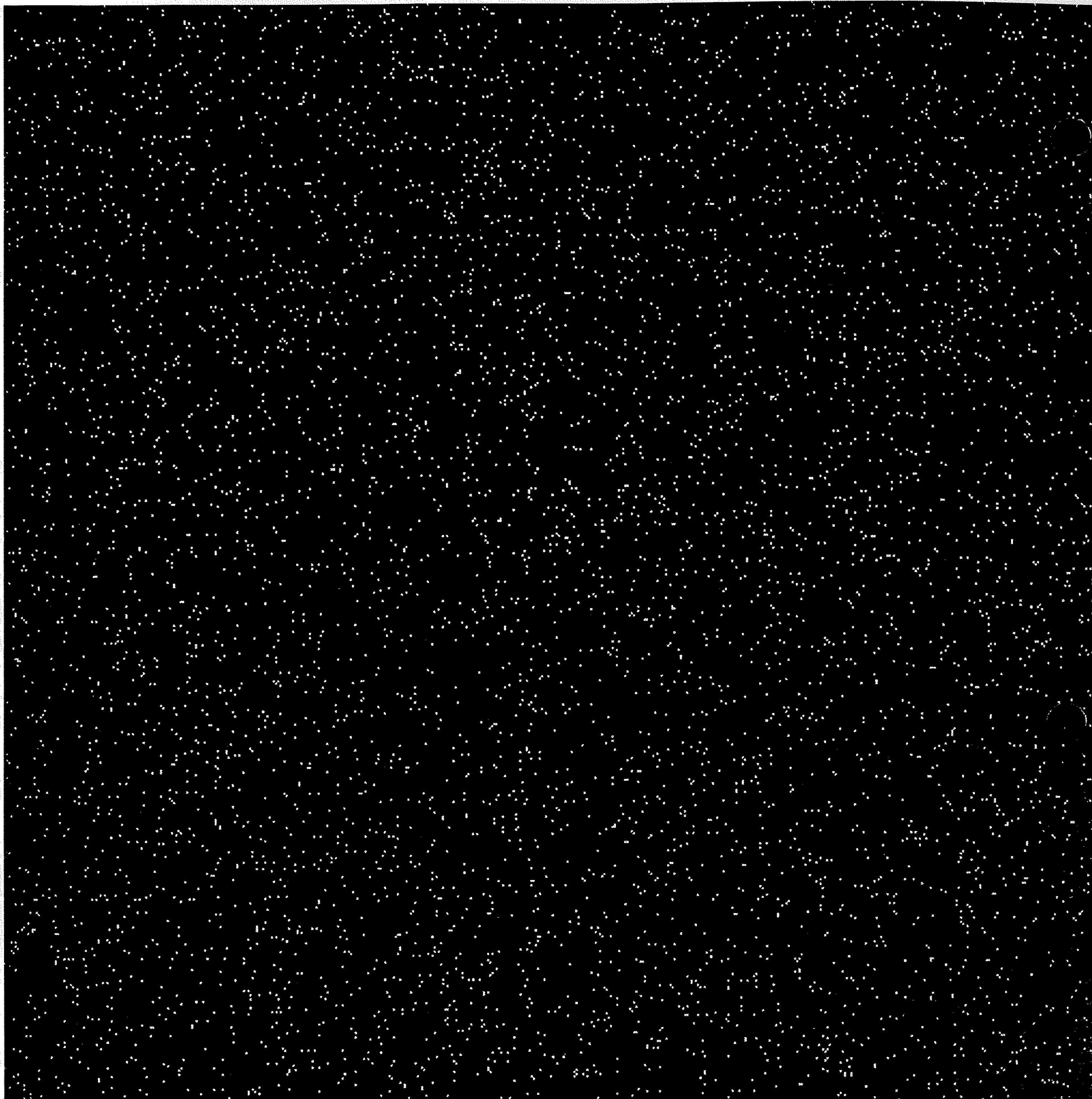


Fe

[illegible].tiff

Zn

egi5_si2na5 SP2.tiff



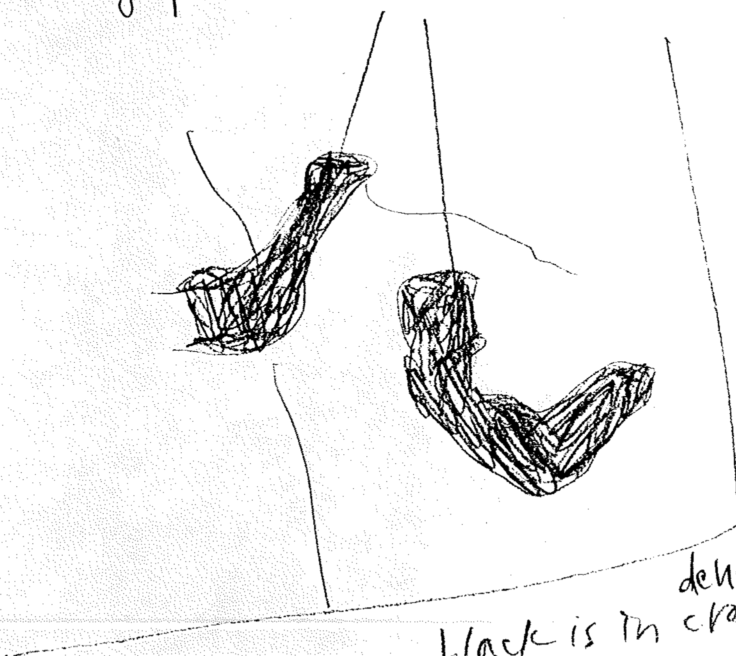
As

eg15 – sitnas SP4. tiff

10-31-00

recovery plant - clay?

has:
m = Mg, Al
M = Fe, Si . tr = Ca



on BSE image - is gray.
on transmitted is black

black is in dehydration cracks in amorphous iron silicate

quant. is not working because clay is in hole - X-rays can't come out

---

back to Iron Arsenide - mapping RR-18

1000x = 100 μm
about 800x

always on LIF = Sp4
↓
As - Si - Fe - S
↑
not working.

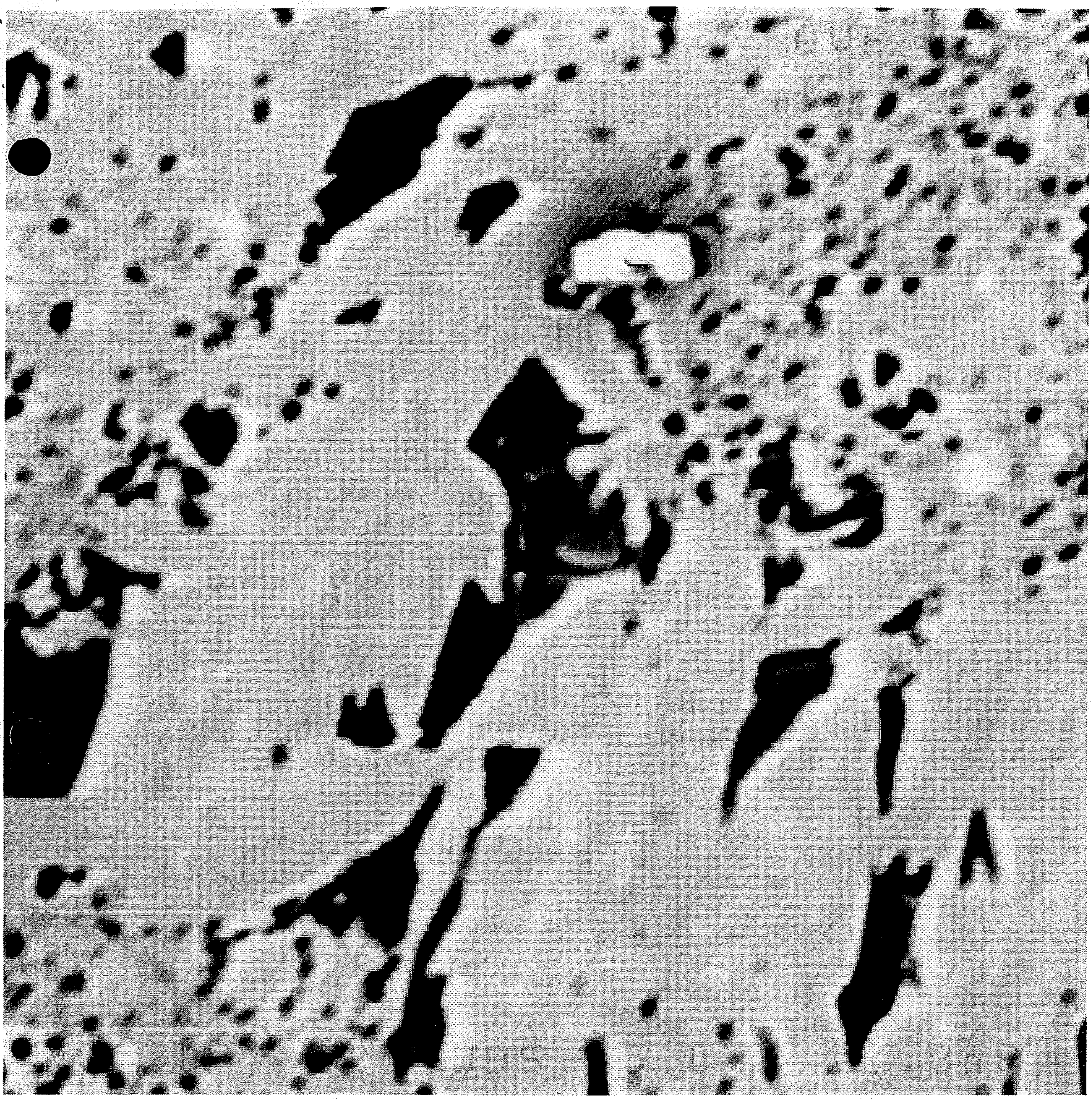
width of image
= 125 μm

RR-18.

Fe	Ba	Ag	Bi	Au	Sb	
26.509	0	0.022	0.369	0	0.313	98.994
28.73	0.056	0	0.787	0	0.698	100.484
28.255	0	0.03	0.496	0.177	0.454	99.555
28.427	0	0	0.562	0.177	0.639	
27.122	0.169	0.032	0.615	0.216	0.375	
28.079	0	0	0.794	0	0.523	
27.91	0.202	0	0.803	0.207	0.675	
28.197	0	0	0.538	0.029	0.533	
27.509	0.101	0.037	0.628	0	0.61	
27.079	0.169	0.082	1.038	0	0.509	
27.312	0.113	0	1.548	0.039	0.734	98.555
28.199	0	0.009	0.326	0	0.665	
28.557	0.011	0.02	0.066	0	0.629	
27.299	0	0	0.431	0.108	0.43	98.345
27.058	0	0.045	0.808	0	0.392	
29.089	0.157	0	0.51	0	0.448	
26.664	0	0.009	0.412	0.03	0.352	
27.844	0.09	0.06	0.994	0.029	0.817	
19.865	0	0.022	0	0	0	42.542
15.431	0.022	0	0	0.01	0.032	51.561
22.712	0.079	0.009	0.206	0	0.326	67.826.

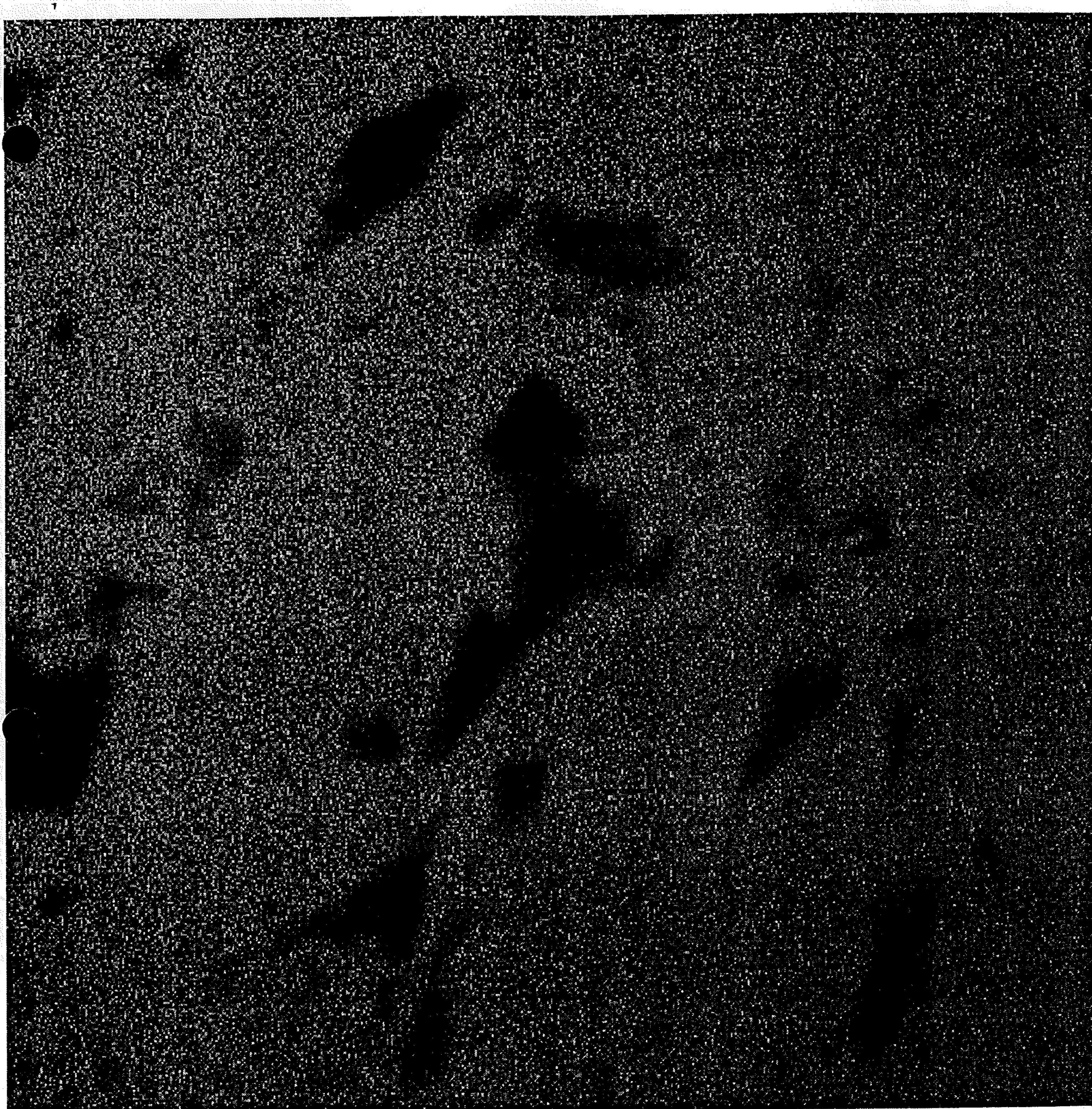
RR-18.

sample #	x	y	z	As	Cu
samp1	-15342	277	-135	70.197	1.584
samp1	-12024	3249	-103	69.459	0.754
samp1	-12940	3193	-103	69.546	0.597
samp1	-13391	3156	-108	69.218	0.603
samp1	-14446	3294	-112	69.578	0.971
samp1	-15232	3267	-114	69.534	0.645
samp1	-15939	3353	-115	69.57	0.824
samp1	-16882	3158	-124	68.777	0.434
samp1	-17707	3233	-130	69.794	1.127
samp1	-18481	3261	-132	69.451	1.095
samp1	-19302	3264	-138	68.809	0.733
samp2	12985	748	6	69.465	0.63
samp2	13906	928	-11	68.488	0.224
samp2	14496	1111	-27	70.077	1.299
samp2	16302	1457	-64	69.825	1.344
samp2	16668	1635	-71	69.146	0.467
samp2	17628	1581	-90	70.505	1.416
samp2	18667	1831	-107	68.045	0.571
samp2	19617	2136	-123	22.655	6.401
samp2	20612	2281	-141	36.066	2.028
samp2	21634	2513	-159	44.494	3.295



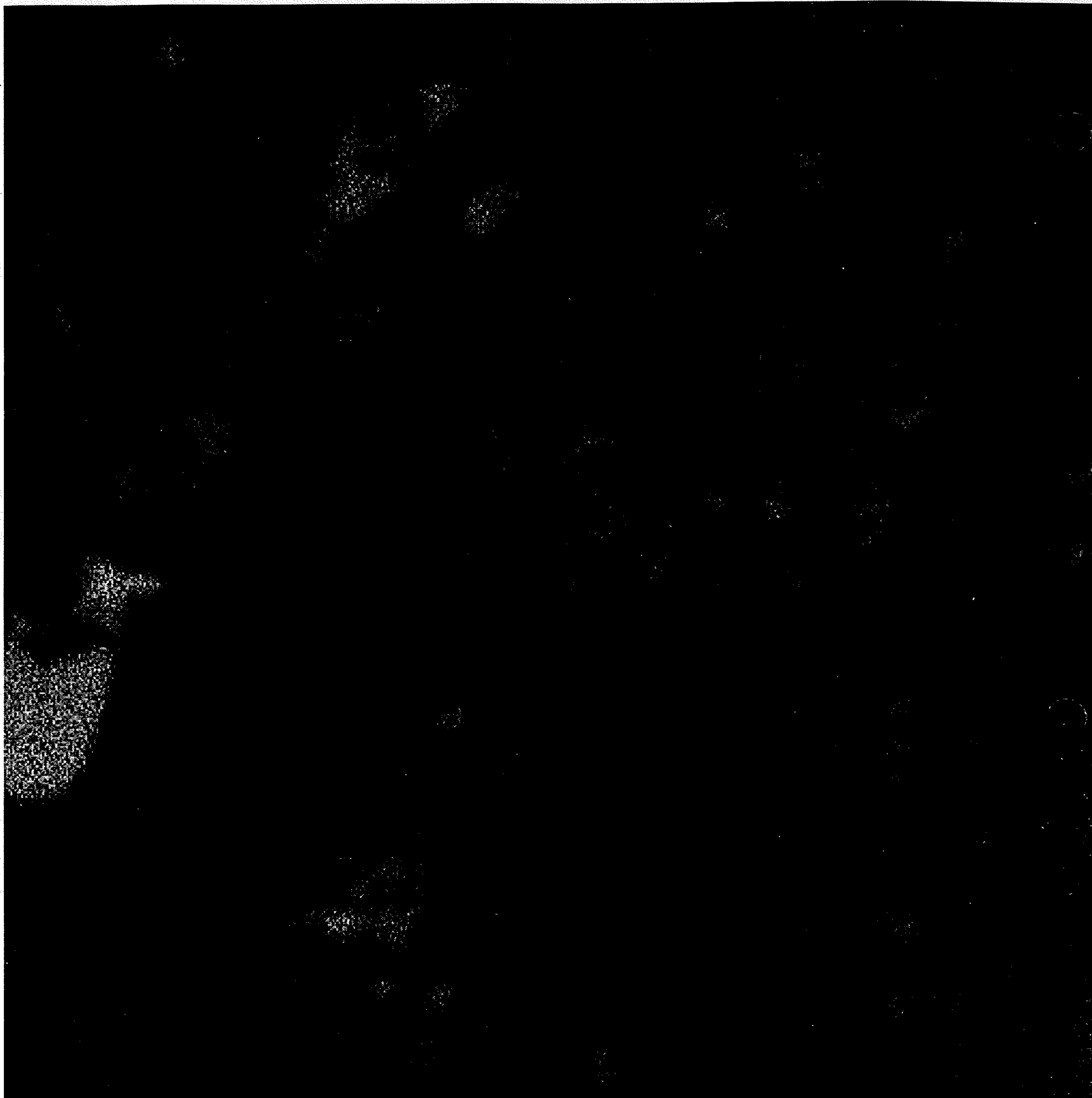
Dec 06, 2000
RR-18

egi_6ascale.ABS.tiff



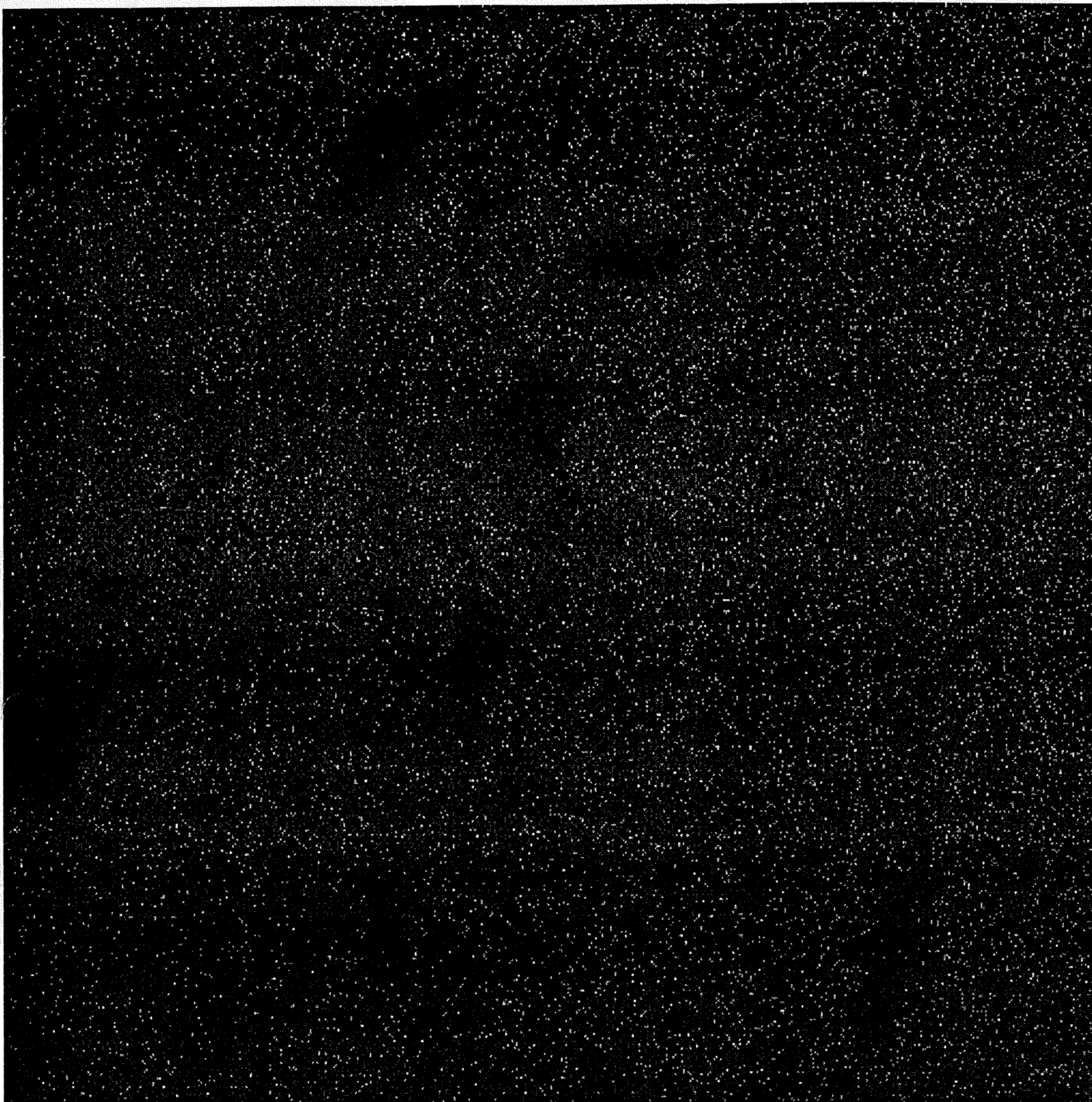
As

eqi_ Gascate SPI. tiff



Ca

tji_basalte SP3.



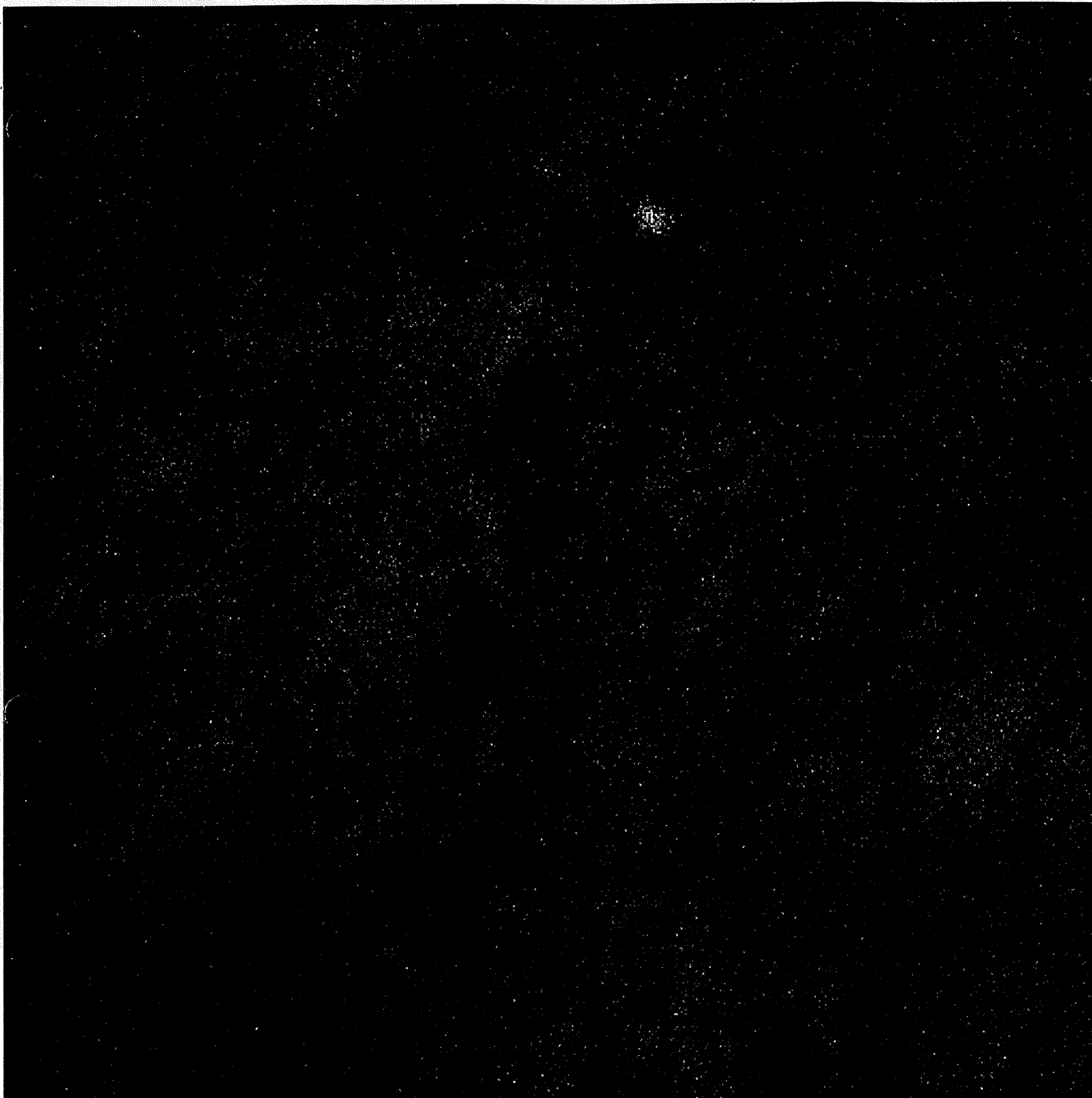
Fe

egi_Gascale 5P4.tiff

Cu

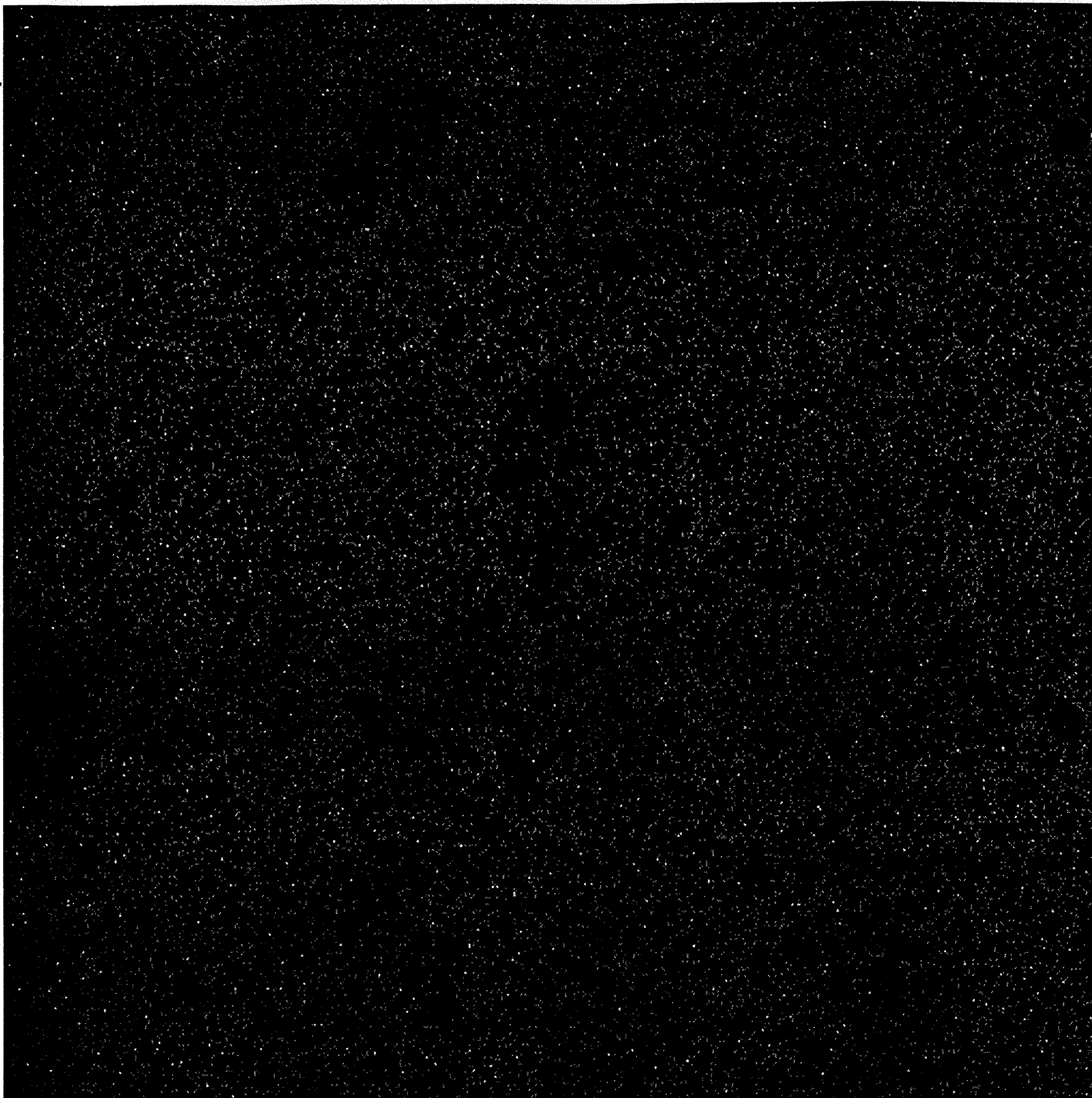
cgi_6cus nispl.tiff

CUS



5

egi_6 cus ni 5/3.tiff



Ni

orj_lov5ni524.tif

SS scale formula
$Fe_2O_3 \cdot 2SiO_2 \cdot 2H_2O$
only .5% Al_2O_3

for Fe^{3+}. Slightly soluble in HCl and H_2SO_4. On heating yields hematite and and tripuhyite. Occurs as a hydrothermal or secondary mineral in Sb–As deposits and in gneisses with other Sb and As minerals. Found at the McDermitt mercury mine, Humboldt Co., NV; at Venesela Mt., AK; at the *Keeley mine, Timiskaming district, South Lorraine Twp., ON, Canada*; Velardeña, DGO, Mexico; La Bassade (Haute Loire) Vosges, France; at Freiberg, Braunsdorf, and Schneeberg, Saxony, Germany; Tafone, Tuscany, Italy; at Smilkov, Votice, and Borenov, Bohemia, Czech Republic; in the Kadamdzhai deposit, Kirgizia; Suzuyama mine, Kagoshima Pref., Japan. EF *AM 43:656(1958), 49:1499(1964); MIN 3(1):503(1972).*

ALLOPHANE GROUP

The allophanes are poorly crystallized or noncrystalline minerals with some ordering when viewed by electron microscopy. *CLM 18:21(1983), SRF(1988), MIN 29(1994).* Members of the group include the following:

ALLOPHANE GROUP

Mineral	
Allophane	71.1.5.1
Hisingerite	71.1.5.2
Imogolite	71.1.5.3
Neotocite	71.1.5.4

71.1.5.1 Allophane $Al_2Si_{1\text{-}2}O_{5\text{-}7}\cdot 2\text{–}3H_2O$

Named in 1816 by Stromeyer from the Greek *to appear [as] another*, in allusion to its change when blowpiped. Allophane group. Synonym: protoallophane. Amorphous or poorly crystalline. Space group unknown. $b = 9.0$, $c = 7.0$. *38-449*(nat): 3.3_{10} 2.25_2 $1.86_{<1}$ 1.40_1 $1.23_{<1}$. Allophane is generally amorphous to X-rays, and is a mineral that has a variable chemical composition. As many as four wide diffraction bands are occasionally observed [*AM 38:634(1953)*] which can disappear on heating to 400° [*CCM 29:124(1981)*] and ^{IV}Al and ^{VI}Al have been determined [*CS 2:1(1964)*], both suggesting some ordering. Numerous TEM studies show that it frequently consists of hollow spheres (~ 35–55 Å with walls 7–10 Å thick and an external water monolayer [*AM 56:465(1971)*], but which can quickly dehydrate and collapse in electron beams. The spheres might be composed of a phyllosilicate structure rolled to reduce bond distortions. *PICC 2:29(1969)*. Spherical halloysite can be mistaken for allophane by TEM. *CCM 11:169(1963)* and others. A defect kaolinite structure has been proposed [*DS 27:537(1979)*], but MAS-NMR studies suggest an octahedral sheet similar to that of 2:1 phyllosilicates, but different from that of kaolinite or gibbsite [*CCM 42:276(1994)*]. Dry grinding can affect allophane morphology [*CM 18:101(1983)*], as can electron beams [*AM 61:379(1976)*]. IR studies have been numerous [e.g., *CCM 28:295,328(1980); 29:124(1981)*] and are similar to those of imogolite. *CCM 28:285(1980)*. **Habit:** Generally occurs as hyaline crusts, masses, and coatings; stalactites and rarely as flowstone. **Physical properties:** White to tan, also bright blue, green, or yellow; frequently stained brown; uncolored streak unless stained; waxy to earthy luster, can be unctuous; sometimes translucent. Conchoidal fracture and then showing a shining luster; brittle; sometimes stalactitic. H = 3. G = 1.8–2.78. Infusible. Gelatinizes in HCl. **Chemistry:** Chemistry is variable, in part due to impurities, and has been assigned a composition $Al_2Si_2O_7 \cdot 3H_2O$ to $Al_2SiO_5 \cdot 2H_2O$ [*AM 52:690(1967)*]: $SiO_2/R_2O_3 \approx$ to 2.0 but frequently near 1:1. Analysis (wt %): SiO_2, 19.71–33.22 (34.80–41.29, Japan); Al_2O_3, 28.24–50.5; Fe_2O_3, generally 0.2–1.0 but to 5–6; MgO, 0–0.18; CaO, 0–2.86; P_2O_5, 0–10.57 (Indiana); SO_3, 0–0.44; H_2O^-, 19.26–22.52; H_2O^+, 9.80–25.0. CEC 69–74 meq per 100 g, also 100 meq per 100 g and varies according to cation. *PSSSA 23:210(1959)*. **Optics:** Isotropic; N = 1.47–1.52; RI increases with Fe_2O_3. **Occurrence:** Principally a weathering product of volcanic ash; also a hydrothermal alteration product of feldspars. Allophane may be a precursor to halloysite, but halloysite has been observed to alter from allophane. *CCM 9:315(1962)*. Citric and humic acids can inhibit the formation of allophane. *PICC 221(1985)*. Frequently found with admixed halloysite, imogolite, limonite, opal, gibbsite, cristobalite, occasionally chrysocolla or evansite, but nearly pure material can occur in sulfide veins or as a coating. Found in sedimentary (sediments, laterites, weathered basalt, marl, chalk, limestone, coal beds, etc.) and hydrothermal (sulfide veins, replacement zones, etc.) environments. Variously abundant or insignificant in soils. **Localities:** Selected localities include: Richmond, MA; Bristol, CT; Morgantown, Berks Co.; Friedensville and Allentown, Lehigh Co.; Rohrs Cave, Lancaster Co., Cornwall, Lebanon Co., PA; Polk Co., TN; Lawrence Co., IN; Alabama Street mine and elsewhere, Saline Co., AR; Kelly mine, Socorro Co., NM; Bisbee, and the Maid of Sunshine mine, Gleeson, Cochise Co., AZ; Cerro Gordo, Inyo Co., CA; Trail Bridge and Crescent Lake, OR; Maui Is., HI; Derbyshire; Wheal Hamblyn, Devon; New Charleton, Kent; Hawkswood mine, North Hill, Cornwall, England; Chessy copper mine, Lyons, Rhône, France; Rosas mine, Sulsis, Sardinia; Calabona mine, Alghero; Cerro del Tasca, Mt. Amiata, Italy; Visé, Belgium; Gräfenthal, near Saalfeld, Thuringia; Schneeberg, and Schwarzenberg, Saxony; Dehrn; in marl at *Gräfenthal, Thuringia, Germany*; Jachymov and Chotina, Bohemia; Petrov, Moravia, Czech Republic; Boleslaw mine, Olkusz, Poland; Vyshkovo region, Transcarpathia, Ukraine; Central Aldan and Podolsk district; Cis-Baikal, Yakutia, Russia; Mbobo Mkulu Cave, Transvaal, South Africa; Alotenango, Guatemala; Guoshan deposit, Fujian Prov., China; northwestern Taiwan; Shishigahana, Mt. Chokai; Fukazawa and Iijima, Nagano Pref.; Kakino pumice, Choyo, and Imogo soil, Hitoyoshi, Kumamoto Pref.; Kanuma and Hangadai, Tochigi Pref.; Oze, Gunma Pref.; Bihoro, Hokkaido Pref.; Kitikami, Iwate

Pref.; Kurayoshi, Tottori Pref.; Ando soil, Okamoto, Japan; Bandung, Java; Sulawesi, Celebes, Indonesia; Aoba, Vanuatu; Mt. Schank, South Australia, Australia; Bealey Spur, Silica Springs, and elsewhere, New Zealand. VK, EF *AM 59:1094(1974), CMB 12:289(1977).*

71.1.5.2 Hisingerite $(Fe,Mn)SiO_3,Fe_2^{3+}Si_2O_7 \cdot 2H_2O$

Named in 1828 by Berzelius for the eminent chemist Wilhelm Hisinger (1766–1852). Allophane group. Synonyms: canbyite, scotiolite, sturtite. Amorphous or MON $a = 5.40$, $b = 9.0$–9.30, $c = 14.99$, $\beta = 98.32°$, $Z = 4$, $D = 3.23$. *26-1140*(nat): 4.23_{10} 2.71_8 2.46_{10} 2.25_8 2.20_8 1.72_{10} 1.57_8 1.55_8. Hisingerite is generally an amorphous substance which frequently yields a small set of wide or diffuse X-ray diffraction peaks. TEM studies [*CCM 35:29(1987)*] reveal that hisingerite consists of hollow spherical particles, generally 100–200 μm but up to 1000 μm in diameter. As sphere size increases, so does smectite content. *NJBM: 321(1982).* The weak X-ray diffraction peaks observed have been variously attributed to those of a smectite [*CUSSGM 19:1(1974)*], mica, or generalized phyllosilicate, but the longest basal spacings of smectite, micas, and so on, have been observed only rarely (Romania). Does not expand with ethylene glycol. Mössbauer and other more recent studies indicate that hisingerite does not have a layer structure. *CM 18:21(1983).* IR, DTA, and TGA did not suggest the presence of hydroxyl. *CCM 32:272(1984).* Hisingerite can be a mixture of amorphous and crystalline materials. *AM 9:1(1924).* Hisingerite can recrystallize to a mixture of ferrian saponite or nontronite + hematite when heated to 180°. **Habit:** Commonly massive and compact. May be minutely spherical. **Physical properties:** Black to brownish black, amber-brown in thinnest slivers and a streak lighter than the massive material; rarely dark red or dark green and photosensitive; resinous to vitreous luster, rarely greasy. Conchoidal fracture but can have a platy parting. [Trace cleavage observed in canbyite (Brandywine).] $H = 3$–$3\frac{1}{2}$. $G = 2.3$–3.0. Decomposed by HCl. Infusible. Can be confused with ferrihydrite. Summary of IR, EPR, Mössbauer data: *MIN 4(2):620(1992).* **Optics:** Isometric; $N = 1.44$–1.73; biaxial; $N_x = 1.562$ (maximum range 1.552–1.595), $N_y = 1.580$, $N_z = 1.582$; 2V(−) very small [also $N_x = 1.715$, $N_z = 1.730$, *PASP 44:279(1944)*]; birefringence = 0.020 (0.015); r > v, parallel extinction; B×O perpendicular to cleavage; orange to golden brown, generally nonpleochroic. **Chemistry:** Hisingerite is generally regarded to have $SiO_2/Fe_2O_3 = 2:1$ with minor substitutions [*CMB 2:294(1955)*], while attempts have been made at rationalizing the alkalis into exchangeable positions [*CCM 32:272(1984)*], frequently with the calculating of a smectite-like formula. Chemical analyses are variable [*DS 36:97(1981)*], but given some high values, such as MgO and/or Al_2O_3, suggest that some materials, perhaps unrecognized as new to the group were included in the survey. Inability to distinguish X-ray amorphous mixtures (opal, etc.) and minor crystalline components could contribute to the uncertainty of some extreme analyses (wt %): SiO_2, most commonly 40.85–49.90 ranging to 27.99–56.91; Fe_2O_3, commonly 14.34–29.00, ranging to 4.80–

40.70; Al_2O_3, ranging 0–22.65; TiO_2, 0–1.88; FeO, 0–6.75 (24.64); MgO, 0–25.95; MnO, 0–3.72; CaO, 0–3.80; Na_2O, 0–2.90; K_2O, 0–1.44; H_2O^+, 3.46–12.10; H_2O^-, 5.53–17.92. CEC_{meas} = 20–74.5 meq per 100 g. **Occurrence:** Originally occurring in large mammillary masses (to many centimeters) and frequently observed in obvious veins, coatings, or crusts. Increasingly observed as microscopic alterations of iron-bearing rocks, especially igneous rocks and ash or glass. Sometimes observed as a thin amber film or as amber globules in amygdules. Frequently veining fayalite, enstatite, and/or amphiboles, sometimes siderite or wollastonite; also alters from pyrrhotite and possibly from chalcopyrite. A component of chlorophaeite and probably in some iddingsite. Observed in recent sediments. Probably formed by meteoric water, also from hot springs. Alters to nontronite; large hisingerite spheres show nontronite alteration rims. *NJBM: 321(1982).* Also occurs as pseudomorphs after hedenbergite. **Localities:** Found in a wide variety of occurrences frequently inconspicuous in quantity and due to its nearly amorphous character difficult to recognize. Selected occurrences include: Tilley Foster mine, Brewster, Putnam Co., NY; Gap nickel mine, Lancaster Co., PA; Brandywine quarry, Wilmington, DE; Alexander Co., NC; Montreal mine, Iron Co., WI; Hibbing, Beaver Bay, and Silver Bay, MN; Castle Dome mine, Gila Co., and on the Mildren and Steppe claims, Cababi district, Pima Co., AZ; Bellvue, Blaine Co., ID; Cardinal mine, Stevens Co., WA; Tetrault mine, Montauban-les-Mines and Hull, QUE; Wilcox mine, Parry Sound, ONT; Nicholson mine, Goldfields, SAS, Canada; Lostwithiel and Wheal Jane, Kea, Cornwall, England; Solberg mine, Elvestorp; Brunjo(!), Västmanland; Sjöström mine, Hofors, Gästrikland; Tunaberg, Långban, and Vestra Silfberg, Värmland; *Riddarhyttan, Västmanland, Sweden*; Helsingfors, and Orijärvi; Degerö mine, Helsinki, Finland; Limburg Sasbach, Kaiserstühl, Germany; Gallego and Aragon rivers, Spain; Făgul Cetatii, Balan, and Masca, Iara Valley, Apuseni Mts., Romania; Atlantis II Deep, Red Sea, Israel; Mt. Karnasurt, Lovozero massif, and Mt. Rasvumchorr, Khibiny massif, Kola Penin.; Ilmen Mts., Urals; Terny Astrobleme, Krivoy Rog, Russia; Zaval'ye, Bug region, Ukraine; Dalnegorsk, Primorsky Krai; Talnakh, Kazakhstan; Gran Canaria, Canary Is.; Llallagua, Bolivia; Suzuyama mine, Kagoshima Pref.; Kawayama mine, Yamaguchi Pref.; Sano mine, Wakayama Pref., Japan; Geelong, VIC; Cobar and Broken Hill, NSW, Australia; Aoba, Vanuatu. Remotely sensed on Mars. VK, EF *SUBBSC 19:9(1974), MIN 4(2):620(1992).*

71.1.5.3 Imogolite $Al_2SiO_3(OH)_4$

Named in 1962 by Yoshinaga and Aomine for the locality. Allophane group. Space group unknown. *38-447*(nat): 21.0_3 11.5_{10} 7.9_8 5.6_2 4.4_1 $3.7_{1.5}$ 3.3_6 2.25_3; *AM 51:327(1987):* 16_{10} 7.9_7 $5.6_{3.5}$ 4.4_1 4.1_1 3.7_2 $3.3_{6.5}$ $2.25_{2.5}$. Imogolite gives relatively few X-ray diffraction peaks, has a tubular structure (17–21 Å outer diameter and 7–10 Å inner diameter) and can appear as partial webs composed of filaments, usually in bundles, in TEM. Imogolite is sometimes characterized by a sharp 19.7 Å peak and broad peaks at 13.3, 7.6, 5.5–5.7, 3.7, 3.3–3.45, 2.25, 2.1, and 1.40 Å. The main peak might be related to a close packing of tubes and the broad peaks relate to a scattering of single tubes. *DS 27:547(1979)*. MAS-NMR studies suggest that imogolite has an octahedral sheet similar to that of 2:1 phyllosilicates but different from that of kaolinite or gibbsite. *CCM 42:276(1994)*. Dry grinding can affect imogolite crystallinity. *CM 16:139(1981)*. Imogolite has been synthesized [*DS 27:547(1979)*] and might form naturally from allophane. The IR of imogolite is similar to allophane [*CCM 28:285(1980)*] and might represent the crystalline equivalent of allophane. *AM 61:379(1976)*. Earthy, composed of microscopic threadlike grains and bundles of fine tubes, each about 20 Å in diameter. Light brownish yellow, also tan to white, blue, green, brown. Conchoidal fracture, brittle. H = 2–3. G = 2.7. Isometric; N = 1.47–1.51 and similar to allophane. RI increases with Fe_2O_3. Principally in soils derived from volcanic ash. Can be found with allophane, halloysite, vermiculite, goethite, gibbsite, quartz, and detrital minerals. Observed in cracks in weathered plagioclase. Citric and humic acids can inhibit the formation of imogolite. *PICC 221(1985)*. Selected localities include: Adirondack Mts., NY; Hawaii Is., HI; Plastic Lake, ONT, Canada; Roudado basalt, Aurillac, Cantal, France; Luochan loess, Shensi Prov.; Guoshan deposit, Fujian Prov., China; Kitakami, Iwate Pref.; Kanto loam, Ibaroki Pref.; (Fukuwa) Kanumatsuchi ash bed, Kanuma and Hangadai, Tochigi Pref.; Kurayoshi, Tottori Pref.; Mitsutsuchi ash bed, Iijima, Nagano Pref.; Uemura, Choyo, and *Imogo soil, Hitoyoshi, Kumamoto Pref., Japan*; New Hebrides; Papua New Guinea; Tirau, Rangitaua, and Wharepaina, New Zealand. VK, EF *SSPN 8:6(1962); AM 54:50(1969); CM 8:87(1969), 12:289(1977); PCM 12:342(1985).*

71.1.5.4 Neotocite $Mn^{3+}SiO_3 \cdot H_2O$

Named in 1848 by Nordenskiöld from the Greek for *new origin*, in allusion to its paragenetic position. Allophane group. Synonyms: stratopeite, penwithite. Isostructural with hisingerite. Amorphous or MON Space group unknown. $b = 9.0–9.30$. *14-172*(nat): 4.36_{10} 3.59_{10} $2.59_{<1}$ 1.54_{10}. Neotocite is generally an amorphous substance but has been observed to yield at least five X-ray diffraction reflections (6.4, 4.36–4.4, 3.5–3.59, 2.59–2.6, 1.54 Å). Neotocite forms 70- to 100-Å microspheroids as for hisingerite and allophane. *CM 18:21(1983)*. When heated to 1000° for 5 minutes, usually yields braunite and minor jacobsite–magnetite and rarely hausmannite; or pyroxmangite (Påjsberg). Brown, brownish black, rarely dark red, amber brown in thinnest slivers, with a brown to dark brown streak. Generally massive and compact; resinous to greasy luster, rarely vitreous to adamantine. Can be photosensitive, changing from red to brown shades on exposure. Conchoidal fracture, brittle. Rarely shows a platy parting (Klapperud). H = 4. G = 2.04–2.8. Decomposed by HCl. Sensitive to relative humidity. DTA, IRA data: *MM 42:279,M26(1978), MIN 4(2):633(1992)*. Isometric; N = 1.475–1.654, usually pale yellow to reddish brown; sometimes birefringent. 2V to 20°. The composition of neotocite is variable [*MM 42:279,M26(1978)*], especially with respect to iron, and a series might extend to hisingerite. Analysis (wt %): SiO_2, 30.0–38.8; Fe_2O_3, 0.01–18.7; Al_2O_3, 0.10–2.9; Mn_2O_3, 0–33.2; FeO, usually 0, also 0.6 (Gastrikland); MnO, 10.4–37.2; TiO_2, 0.01; MgO, 0.5–9.6; CaO, 0.1–2.3; Na_2O, 0.02–0.3; K_2O, 0.01–0.3; CO_2, 2.2–7.4; H_2O^+, 8.2–11.8; H_2O^-, 7.04 (WI). See also *MIN 4(2):633(1992)*. Associated wtih rhodonite, rhodochrosite, quartz, manganese phosphates, spessartine, bementite, tephroite, and others. Can have admixed birnessite. Frequently observed in obvious veins, coatings, or crusts. Observed as microscopic alterations of manganese-bearing rocks or minerals, also manganese-bearing ophiolite. Frequently veining weathered manganese-bearing pyroxenes, especially rhodonite, and spessartine. Found lining fractures in granite pegmatite and in association with manganese-bearing minerals or rocks, but due to its nearly amorphous character, difficult to recognize. Selected occurrences include: Plainfield, MA; Bald Knob, Alleghany Co.; Foote mine, Kings Mt., Cleveland Co., NC; Montreal mine, Gogebic Range, Iron Co., WI; Batesville, Independence Co., AR; Bromide district, OK; Aravaipa district, Graham Co. and Ajo, AZ; in several locations in CA, including Johe Ranch mine, San Luis Obisbo Co., Lake Elsinore area, Riverside Co., and in the Charles Mt. deposit, Humboldt Co.; Anacortes and elsewhere, Olympic Penin., WA; El Fino mine, Pinar del Rio Prov.; Polaris mine, Candelaria district and elsewhere, Bueycito, Oriente Prov., Cuba; Bambolita mine, Moctezuma, SON, Mexico; Llanfaerhys, Rhiw, Wales; Wheal Owles, Penwith, and Geevor mine, St. Just, Cornwall, England; Brevik, West Gothland, Norway; Klapperud, Dalsland; Delecarlia; Gillinge mine, Svärta, Södermanland; at Långban, Jakobsberg, and the Harstig mine, Pajsberg, and Filipstad, Vårmland; *Erik-Ers mine, Torsåker, Gästrikland, Sweden*; also in the Brunsjö mine, near Grythyttan, Örebro; Wittingi, Storkyro, Finland; Herborn, Dillinberg, Germany; Chiavari, Liguria, and Val Graveglia, Genoa, Italy; Litosice, Iron Mts., Czech Republic; Yakobeni, Romania; Malo-Sedelnikovsk, Middle Ural Mts., Russia; Tien Shan, Kirghizstan; Lafaiete district, MG, Brazil; Broken Hill, NSW, Australia; Shidara, Aichi Pref.; Kawazu mine, Shizuoka Pref., Noda–Tamagawa mine, Iwate Pref., Japan. VK, EF *AM 46:1412(1961), MIN 4(2):633(1992).*

PYROPHYLLITE TALC GROUP

The pyrophyllite talc group minerals are phyllosilicates corresponding to the general formula

$$R_2^{3+}Si_4O_{10}(OH)_2 \quad \text{for the dioctahedral pyrophyllite subgroup}$$

$$R_3^{2+}Si_4O_{10}(OH)_2 \quad \text{for the trioctahedral talc subgroup}$$

where

$R^{3+} = Al, Fe^{3+}$

$R^{2+} = Mg, Fe^{2+}, Ni^{2+}$

	Name	Formula				File No.
i	Copper Aluminum Phc... Hydroxide Hydrate :/Turquoise	$CuAl_6(PO_4)_4(OH)_8 \cdot 5H_2O$	3.68_x	2.91_8	6.17_7	6- 214
*	Copper Aluminum Scandium Oxide :	$ScAlCuO_4$	2.69_x	2.82_9	2.57_9	38-1102
i	Copper Aluminum Silicate Hydroxide : Calcium/Papagoite	$CaCuAl(SiO_3)_2(OH)_3$	2.87_x	4.29_9	2.20_9	13- 372
o	Copper Aluminum Silicate Hydroxide Hydrate : Potassium Sodium/Ajoite	$(K,Na)Cu_7AlSi_9O_{24}(OH)_6 \cdot 3H_2O$	12.3_x	2.46_1	4.08_1	35- 477
i	Copper Aluminum Silicate Hydroxide : Potassium	$KCu_3AlSi_3O_{10}(OH)_2$	10.2_x	3.38_4	2.62_4	24- 844
	Copper Aluminum Sulfate Hydroxide Hydrate :/Woodwardite	$Cu_4Al_2(SO_4)(OH)_{12} \cdot 3H_2O$	10.9_x	5.46_6	3.66_5	39- 726
o	Copper Aluminum Sulfate Hydroxide Hydrate :/Cyanotrichite	$Cu_4Al_2SO_4(OH)_{12} \cdot 2H_2O$	10.2_x	3.88_9	5.26_8	11- 131
	Copper Aluminum Sulfate Hydroxide Hydrate :/Woodwardite	$Cu_4Al_2(SO_4)(OH)_{12} \cdot xH_2O$	9.10_x	2.58_6	1.50_6	29- 529
	Copper Aluminum Sulfate Hydroxide Hydrate :/Chalcoalumite	$CuAl_4SO_4(OH)_{12} \cdot 3H_2O$	8.92_x	8.29_x	4.24_x	8- 142
i	Copper Aluminum Sulfate Hydroxide Hydrate :/Chalcoalumite	$CuAl_4SO_4(OH)_{12} \cdot 3H_2O$	8.50_x	4.25_9	4.18_3	25-1430
i	Copper Aluminum Sulfate Hydroxide : Lead/Osarizawaite	$Pb(Al,Cu)_3(SO_4)_2(OH)_6$	3.00_x	5.75_8	3.52_6	15- 178
	Copper Aluminum Sulfide :	$CuAlS_2$	3.04_x	1.86_x	1.60_6	25- 14
	Copper Aluminum Sulfide :	$CuAl_2S_4$	1.76_x	2.49_9	2.87_8	25- 13
	Copper Ammine Bromide :	α-$Cu(NH_3)_2Br_2$	2.04_x	3.00_x	1.74_x	19- 422
i	Copper Ammine Bromide :	$Cu(NH_3)_6Br_2$	1.80_x	2.99_x	2.15_x	20- 346
	Copper Ammine Chloride :	$Cu(NH_3)_6Cl_2$	1.99_x	3.50_9	2.60_9	20- 347
	Copper Ammine Chromium Oxide :	$(Cu(NH_3)_4)CrO_4$	3.59_x	4.21_8	5.20_6	28- 393
*	Copper Ammine Fluoride Hydrate : Beryllium	$Cu(NH_3)_4BeF_4 \cdot H_2O$	4.57_x	3.00_8	3.42_6	25-1429
	Copper Ammine Manganese Oxide :	$(Cu(NH_3)_4)(MnO_4)_2$	4.54_x	4.60_8	3.31_6	28- 394
o	Copper Ammine Molybdenum Oxide :	$(NH_3)_4CuMoO_4$	5.01_x	4.45_x	3.49_x	33- 449
	Copper Ammine Molybdenum Oxide :	$(Cu(NH_3)_4)MoO_4$	3.62_x	5.28_6	4.99_6	28- 395
	Copper Ammine Nitrate :	$Cu(NH_3)_2NO_3$	3.10_x	3.96_5	2.26_5	3- 553
	Copper Ammine Oxalate Hydrate :	$C_2H_6CuN_2O_4 \cdot 2H_2O$	6.00_x	4.31_x	5.33_9	26- 500
	Copper Ammine Platinum Chloride :	$(Cu(NH_3)_4)PtCl_4$	6.47_x	2.87_x	5.28_8	16- 92
o	Copper Ammine Rhenium Oxide :	$Cu(NH_3)_4(ReO_4)_2$	5.34_x	4.99_x	3.62_x	37- 662
	Copper Ammine Rhenium Oxide :	$(Cu(NH_3)_4)(ReO_4)_2$	5.11_x	4.73_4	3.92_2	28- 396
c	Copper Ammine Selenate :	$Cu(NH_3)_4SeO_4$	3.58_x	5.00_9	5.13_8	24-1268
	Copper Ammine Sulfate :	$Cu(NH_3)_4SO_4$	4.02_x	3.05_3	2.11_3	3- 273
i	Copper Ammine Sulfate Hydrate :	$Cu(NH_3)_4SO_4 \cdot H_2O$	4.02_x	5.24_6	5.30_5	20- 349
c	Copper Ammine Sulfate Hydrate :	$Cu(NH_3)_4SO_4 \cdot H_2O$	4.01_x	5.29_5	5.22_4	24-1269
	Copper Ammine Tungsten Oxide :	$(Cu(NH_3)_4)WO_4$	5.27_x	4.99_8	3.62_6	28- 397
	Copper Ammine Vanadium Oxide Hydrate :	$(Cu(NH_3)_4) \cdot (VO_3)_2 \cdot 2H_2O$	5.82_x	4.15_x	4.07_x	20- 350
o	Copper Ammonia Molybdenum Oxide Hydrate :	$CuMoO_4N_{0.42}H_{1.26} \cdot 2.4H_2O$	3.34_x	3.78_8	5.12_7	31- 449
i	Copper Ammonium Phosphate :	$Cu_3(NH_4)_2(PO_3)_8$	3.31_x	3.23_x	2.85_x	29- 530
i	Copper Ammonium Thiocarbonate :	NH_4CuCS_3	9.92_x	5.21_7	7.10_6	27-1009
i	Copper : Antimony	Cu_3Sb	2.09_x	2.38_8	2.19_7	11- 72
i	Copper : Antimony	$Cu_{3.3}Sb$	2.09_x	2.38_9	2.16_9	12- 75
	Copper Antimony Arsenic Sulfide :	$As_{1.218}Cu_4Sb_{0.782}S_5$	2.99_x	1.83_8	1.56_7	34- 809
i	Copper Antimony Arsenic Tellurium Sulfide :/Goldfieldite	$Cu_{12}(Te,As,Sb)_4S_{13}$	2.97_x	1.82_6	3.64_3	29- 531
c	Copper : Antimony Cadmium	$CdCuSb$	2.22_x	3.14_5	1.28_2	25-1213
o	Copper : Antimony Cadmium	Cu_4CdSb	2.12_x	2.98_8	1.50_8	38- 766
i	Copper Antimony Chloride Arsenate Hydroxide Hyd : Cal/Richelsdorfite	$Ca_2Cu_5SbCl(OH)_6(AsO_4)_4 \cdot 6H_2O$	3.05_x	4.91_7	4.39_6	35- 585
*	Copper Antimony Oxide :	$CuSb_2O_6$	3.27_x	2.58_4	2.60_2	17- 284†
	Copper Antimony Oxide :	$Cu_4SbO_{4.5}$	2.88_x	2.38_9	2.51_7	36-1106
i	Copper Antimony Oxide :	$Cu_9Sb_4O_{19}$	2.78_x	1.70_3	2.41_3	37-1094
	Copper Antimony Oxide Hydroxide :/Partzite	$Cu_2Sb_2(O,OH)_7$	2.95_x	5.91_9	1.81_8	7- 303
i	Copper Antimony Selenide :/Permingeatite	Cu_3SbSe_4	3.25_x	1.99_9	1.70_8	25- 263
i	Copper Antimony Sulfide :/Chalcostibite, syn	$CuSbS_2$	3.14_x	2.99_x	3.11_9	35- 413
	Copper Antimony Sulfide :/Chalcostibite, syn	$CuSbS_2$	3.11_x	3.09_9	2.99_9	24- 347
*	Copper Antimony Sulfide :/Famatinite, syn	Cu_3SbS_4	3.11_x	1.90_7	1.62_4	35- 581
*	Copper Antimony Sulfide :	$Cu_{13.72}Sb_{4.09}S_{13}$	3.02_x	1.85_5	2.61_3	24-1317†
*	Copper Antimony Sulfide :	Cu_3SbS_3	3.01_x	1.84_7	3.69_3	31- 450
*	Copper Antimony Sulfide :/Tetrahedrite, syn	$Cu_{12}Sb_4S_{13}$	2.98_x	1.83_4	2.58_3	24-1318†
i	Copper Antimony Sulfide :/Skinnerite, syn	Cu_3SbS_3	2.83_x	2.63_9	2.62_9	26-1110
*	Copper Antimony Sulfide : Silver/Polybasite, syn	$(Ag,Cu)_{16}Sb_2S_{11}$	3.15_x	2.98_x	2.86_x	36- 391
i	Copper Antimony Sulfide : Thallium/Rohaite	$TlCu_5SbS_2$	3.08_x	2.39_x	3.80_9	39- 412
	Copper Arsenate :/Trippkeite, syn	$CuAs_2O_4$	3.16_x	6.07_6	3.04_5	31- 451
	Copper Arsenate :	$Cu_3As_2O_8$	3.03_x	2.85_x	3.12_8	11- 160
o	Copper Arsenate :	$Cu_2As_2O_7$	3.03_x	2.59_7	3.30_5	33- 450
*	Copper Arsenate :/Lammerite	$Cu_3(AsO_4)_2$	2.89_x	3.07_5	3.00_5	39- 385
	Copper Arsenate Carbonate Hydroxide Hydrate : Calcium/Tyrolite	$CaCu_5(AsO_4)_2(CO_3)(OH)_4 \cdot 6H_2O$	28.0_x	14.1_8	2.98_8	11- 348
	Copper Arsenate Hydrate :/Mixite	$Cu_3(AsO_4)_2 \cdot 6H_2O$	12.1_x	2.46_9	4.48_8	13- 413
	Copper Arsenate Hydrate :	$Cu_5As_4O_{15} \cdot 10H_2O$	11.0_x	3.93_7	2.94_7	11- 164
o	Copper Arsenate Hydrate :/Lindackerite	$Cu_5As_4O_{15} \cdot 9H_2O$	10.2_x	3.19_8	3.95_6	11- 166
	Copper Arsenate Hydrate :	$Cu_2As_2O_7 \cdot 3H_2O$	7.82_x	3.10_x	3.94_8	11- 162
	Copper Arsenate Hydrate :	$Cu_5As_2O_{10} \cdot 5H_2O$	3.94_x	3.54_x	2.55_x	11- 163
o	Copper Arsenate Hydrate : Lead/Thometzekite	$PbCu_2(AsO_4)_2 \cdot 2H_2O$	3.27_x	4.69_8	2.96_7	39- 340
	Copper Arsenate Hydroxide :/Cornubite	$Cu_5(AsO_4)_2(OH)_4$	4.72_x	2.56_x	2.49_x	38- 441
*	Copper Arsenate Hydroxide :/Clinoclase	$Cu_3(AsO_4)(OH)_3$	3.58_x	3.14_3	7.17_1	37- 447
	Copper Arsenate Hydroxide :/Olivenite	$Cu_2AsO_4(OH)$	2.98_x	4.82_9	5.91_7	4- 657

	Name	Formula				File No.
*	Copper Arsenate Hydroxide :/Cornwallite	$Cu_5(AsO_4)_2(OH)_4$	2.41_x	[illegible]	3.53_5	39-1357
i	Copper Arsenate Hydroxide : Calcium/Conichalcite	$CaCu(AsO_4)(OH)$	2.84_x	3.12_8	2.60_7	37- 448
	Copper Arsenate Hydroxide Hydrate :/Strashimirite	$Cu_8(AsO_4)_4(OH)_4 \cdot 5H_2O$	18.7_x	2.86_x	8.97_9	21- 289
*	Copper Arsenate Hydroxide Hydrate :/Euchroite	$Cu_2(AsO_4)(OH) \cdot 3H_2O$	7.29_x	5.23_x	2.83_9	39-1358
o	Copper Arsenate Hydroxide Hydrate :/Arhbarite	$Cu_2(AsO_4)(OH) \cdot 6H_2O$	4.57_x	4.51_9	3.72_6	35- 562
	Copper Arsenate Hydroxide : Lead/Duftite	$PbCuAsO_4(OH)$	3.26_x	2.85_8	2.65_8	14- 169
i	Copper Arsenate : Potassium	$K_2CuAs_2O_7$	3.12_x	1.93_3	5.73_3	34- 448
	Copper Arsenate : Silver	$AgCu_4(AsO_4)_3$	2.68_x	2.82_8	1.56_8	39- 876
o	Copper Arsenate Sulfate :/Unnamed mineral [NR]	CuO-As_2O_5-SO_2	10.7_x	2.59_x	4.57_8	29- 532
i	Copper Arsenate Sulfate Hydroxide Hydrate :/Parnauite	$Cu_9(AsO_4)_2(SO_4)(OH)_{10} \cdot 7H_2O$	14.3_x	4.52_6	10.4_3	29- 533
c	Copper Arsenic Antimony Sulfide :/Luzonite, antimonian	$Cu_3(As_{0.64}Sb_{0.36})S_4$	3.07_x	1.88_3	1.61_2	25- 285
c	Copper : Arsenic Barium	$AsBaCu$	2.91_x	2.19_4	1.57_2	33- 123†
o	Copper Arsenic Fluoride :	$CuF_2 \cdot AsF_5$	5.73_x	4.88_x	3.61_x	36- 562
i	Copper Arsenic Fluoride :	$CuAsF_6$	3.74_x	2.74_8	1.72_8	31- 452
	Copper Arsenic Selenide :	$CuAsSe_2$	3.98_x	3.18_x	3.03_x	37-1182
o	Copper Arsenic Selenide :	Cu_3AsSe_3	3.68_x	2.90_x	2.86_x	38- 878
i	Copper Arsenic Selenide :	$Cu_4As_2Se_5$	3.20_x	3.18_x	1.96_x	37-1181
i	Copper Arsenic Selenide :	$CuAsSe$	3.20_x	1.96_x	3.34_4	36- 945
	Copper Arsenic Selenide :/Mgriite	Cu_3AsSe_3	3.18_x	1.95_x	1.67_5	35- 675
o	Copper Arsenic Selenide :	$Cu_6As_4Se_9$	3.16_x	1.95_5	1.66_3	36-1309
o	Copper Arsenic Selenide :	Cu_3AsSe_3	1.96_x	1.68_x	3.20_8	27- 148
i	Copper Arsenic Selenide Sulfide :	$CuAsSe_{0.8}S_{0.2}$	3.18_x	1.94_8	3.25_4	36- 946
*	Copper Arsenic Sulfide :/Enargite	Cu_3AsS_4	3.22_x	3.21_x	2.85_8	35- 775
c	Copper Arsenic Sulfide :/Lautite	$CuAsS$	3.11_x	3.09_9	1.91_4	25-1179
i	Copper Arsenic Sulfide :/Lautite	$CuAsS$	3.11_x	1.91_3	1.89_1	39- 393
	Copper Arsenic Sulfide :/Luzonite, syn	Cu_3AsS_4	3.05_x	1.86_9	1.59_7	10- 450
o	Copper Arsenic Sulfide :/Arsenosulvanite	Cu_3AsS_4	3.04_x	1.87_x	1.59_5	25- 265
	Copper Arsenic Sulfide :/Sinnerite, syn	$Cu_6As_4S_9$	3.02_x	1.85_8	1.58_7	25- 264
	Copper Arsenic Sulfide :	$Cu_{24}As_{12}S_{31}$	2.99_x	1.84_8	1.57_7	27- 146
i	Copper Arsenic Sulfide : Silver/Pearceite, syn	$(Ag,Cu)_{16}As_2S_{11}$	2.98_x	2.81_9	3.07_7	36- 393
	Copper Arsenic Tin Vanadium Sulfide :/Colusite	$Cu_3(As,Sn,V)S_4$	3.07_x	1.88_6	1.60_4	9- 10
i	Copper Arsenic Vanadium Sulfide :/Arsenosulvanite, syn	$Cu_3(As,V)S_4$	3.04_x	1.86_7	1.59_5	35-1017
i	Copper Arsenide :/Paxite	$CuAs_2$	3.14_x	2.62_x	2.50_9	39- 369
i	Copper Arsenide :	$Cu_{9.5}As_4$	2.09_x	2.03_x	2.00_x	21- 280
	Copper Arsenide :/Koutekite	Cu_5As_2	2.09_x	2.02_x	2.00_x	29- 534
	Copper Arsenide :	Cu_5As_2	2.08_x	2.02_x	1.99_x	24- 351
i	Copper Arsenide :/Koutekite, syn	Cu_5As_2	2.08_x	2.02_x	1.99_x	13- 581
	Copper Arsenide :/Domeykite-β	β-Cu_3As	2.08_x	2.02_x	1.45_5	14- 454
	Copper Arsenide :	Cu_5As_2	2.08_x	1.99_x	2.02_9	23- 197
i	Copper Arsenide :	As_2Cu_5	2.07_x	1.20_8	1.76_6	21- 279
o	Copper Arsenide :/Domeykite-β, syn	β-Cu_3As	2.05_x	2.00_x	2.34_8	2-1251
	Copper Arsenide :/Domeykite	Cu_3As	2.05_x	1.89_7	1.97_5	9- 333
i	Copper Arsenide :	Cu_2As	1.99_x	2.45_7	1.90_6	25- 266
	Copper Arsenide :/Algodonite	Cu_6As	1.99_x	2.11_4	2.25_2	9- 429
c	Copper Arsenide : Potassium	K_2CuAs	2.71_x	5.01_7	3.05_5	30- 931†
c	Copper Arsenide : Sodium	Na_2CuAs	4.43_x	3.86_7	2.43_7	30-1185†
*	Copper Arsenide Sulfide :/Enargite, syn	Cu_3AsS_4	1.73_x	3.07_x	2.84_8	35- 580
i	Copper Azide :	$Cu(N_3)_2$	7.52_x	3.19_8	2.80_8	21- 281
	Copper Azide :	CuN_3	3.06_x	4.69_8	3.18_8	4- 622
c	Copper : Barium	$BaCu_{13}$	1.98_x	2.39_9	2.62_5	25-1210
*	Copper Barium Oxide :	Cu_2BaO_2	2.48_x	2.90_9	2.86_6	39- 245
	Copper : Beryllium	Be_2Cu	2.10_x	1.80_x	3.44_8	3- 993
	Copper : Beryllium	$BeCu$	1.93_x	2.73_2	1.56_2	31- 182
i	Copper Bismuth Arsenate Hydroxide Hydrate :/Mixite	$BiCu_6(AsO_4)_3(OH)_6 \cdot 3H_2O$	12.0_x	2.46_9	3.57_8	13- 414
i	Copper Bismuth Oxide :	$CuBi_2O_4$	3.18_x	1.95_3	2.69_3	26- 502
c	Copper Bismuth Sulfide :	$Cu_4Bi_5S_{10}$	3.14_x	3.62_7	3.08_6	29- 535†
	Copper Bismuth Sulfide :/Hodrushite	$Cu_8Bi_{12}S_{22}$	3.10_x	3.62_8	2.72_8	25- 267
i	Copper Bismuth Sulfide :/Cuprobismutite, syn	$Cu_4Bi_7S_{12}$	3.08_x	2.72_6	3.62_5	29- 536
	Copper Bismuth Sulfide :/Emplectite	$CuBiS_2$	3.05_x	3.23_9	3.13_7	10- 474
	Copper Bismuth Sulfide :/Wittichenite	Cu_3BiS_3	2.85_x	3.08_8	4.55_4	9- 488
	Copper Bismuth Sulfide :	$Cu_3Bi_3S_7$	2.77_x	1.87_x	3.11_8	27- 149
i	Copper Bismuth Sulfide : Lead Silver/Berryite	$Pb_3(Cu,Ag)_5Bi_7S_{16}$	3.51_x	2.91_x	3.50_9	19- 703
	Copper Bismuth Sulfide : Lead Silver/Berryite	$Pb_2(Ag,Cu)_3Bi_5S_{11}$	3.47_x	2.89_8	2.80_7	19- 702
o	Copper Bismuth Sulfide : Lead Silver	Pb-Ag-Cu-Bi-S	2.82_x	3.47_7	2.00_6	9- 420
o	Copper Bismuth Sulfide : Silver/Unnamed mineral [NR]	$(Ag,Cu)_{0.8}Bi_{2.2}S_5$	3.48_x	2.83_9	3.61_6	22-1325
o	Copper Bismuth Sulfide : Silver	$(Ag,Cu)_2Bi_4S_7$	2.89_x	2.00_8	3.47_7	22-1327
i	Copper Bismuth Vanadium Oxide :/Namibite	$CuBi_2VO_6$	3.02_x	3.57_8	5.58_7	35- 711
i	Copper Borate :	CuB_2O_4	3.79_x	3.63_5	2.77_5	25- 268
i	Copper Borate :	$Cu_3B_2O_6$	2.94_x	2.88_x	2.64_1	32- 324†
	Copper Borate :	$CuBO_2$	2.93_x	3.27_8	2.88_8	28-1256

in this group

							File No.
i	Cobalt Sulfate Hydrate :	**Bieberite, syn**	4.87_x	3.76_8	4.82_6	2.73_3	**16– 487**
*	Cobalt Sulfate Hydrate :	**Aplowite, syn**	4.46_x	5.44_9	3.94_5	6.82_4	**16– 488**
i	Cobalt Sulfate Hydrate :	**Moorhouseite**	4.38_x	4.02_6	5.45_3	5.85_3	**16– 304**
	Cobalt Sulfide :	**Linnaeite**	2.83_x	1.67_8	2.36_7	1.82_6	**11– 121**
	Cobalt Sulfide :	**Cattierite, syn**	1.67_x	2.77_7	2.48_4	1.06_x	**19– 362**
	Cobalt Sulfide :	**Linnaeite, syn**	1.66_x	2.83_6	2.35_4	1.05_6	**19– 367**
	Cobalt Sulfide : Antimony	**Costibite**	2.60_x	2.50_9	1.91_8	2.90_6	**22–1082**
	Cobalt Sulfide : Antimony	**Paracostibite, syn**	2.56_x	2.03_9	2.88_7	0.96_8	**23–1062**
i	Cobalt Sulfide : Copper	**Carrollite**	2.86_x	1.67_8	1.83_6	2.37_5	**9– 425**
i	Cobalt Sulfide : Nickel	**Siegenite, syn**	2.83_x	1.66_8	2.35_5	1.81_4	**20– 782**
	Cobalt Telluride :	**Mattagamite, syn**	2.82_x	2.71_x	2.07_x	3.31_8	**11– 553**
	Cobalt Thiocyanate Hydrate : Sodium	**Julienite**	3.55_8	3.23_8	1.38_8	0.94_x	**2– 372**
	Cobalt Uranyl Arsenate Hydrate :	**Metakirchheimerite**	8.78_x	3.57_x	5.08_6	4.30_6	**12– 586**
	Cobalt Uranyl Sulfate Hydroxide Hydrate :	**Cobalt-zippeite, syn**	7.21_x	3.59_5	3.12_3	3.47_2	**29– 520**
	Cobalt Zinc Arsenite Hydroxide Hydrate :	**Cobaltkoritnigite**	7.94_x	3.14_7	3.82_5	3.25_4	**35– 499**
*	Copper :	**Copper, syn**	2.09_x	1.81_5	1.28_2	1.09_2	**4– 836**
	Copper Aluminum Antimony Oxide Hydrate :	**Cyanophillite**	4.84_x	9.67_6	2.59_6	2.44_5	**35– 507**
i	Copper Aluminum Arsenate Hydroxide Hydrate :	**Goudeyite**	11.6_x	2.92_5	4.41_5	3.24_5	**29– 526**
*	Copper Aluminum Arsenate Hydroxide Hydrate :	**Liroconite**	6.52_x	6.03_8	3.01_5	2.70_3	**12– 526**
i	Copper Aluminum Arsenate Hydroxide Hydrate :	**Ceruleite**	5.65_x	7.30_8	5.93_7	4.76_7	**29– 525**
i	Copper Aluminum Arsenate Hydroxide Hydrate :	**Luetheite**	3.50_x	7.21_7	2.51_5	1.80_5	**29– 527**
	Copper Aluminum Arsenate Sulfate Hydroxide Hydrate :	**Chalcophyllite**	9.54_x	4.79_x	2.59_x	2.34_x	**19– 379**
o	Copper Aluminum Carbonate Sulfate Hydroxide Hydrate :	**Carbonate-cyanotrichite**	4.21_x	10.1_x	5.03_6	3.33_6	**16– 365**
	Copper Aluminum Chloride Sulfate Hydrate :	**Aubertite**	4.50_x	4.25_7	3.95_6	6.25_5	**33– 447**
	Copper Aluminum Chloride Sulfate Hydroxide Hydrate :	**Spangolite**	7.10_x	3.59_8	2.54_7	1.80_7	**5– 142**
i	Copper Aluminum Iron Phosphate Hydroxide Hydrate :	**Turquoise, ferrian**	3.70_x	2.93_x	3.31_7	2.91_7	**25– 260**
c	Copper Aluminum Iron Sulfate Hydroxide : Lead	**Osarizawaite**	5.77_x	3.01_8	3.54_4	2.29_3	**34– 165**
	Copper Aluminum Phosphate Hydroxide Hydrate :	**Zapatalite**	7.62_x	11.6_x	5.75_8	6.82_7	**25– 261**
i	Copper Aluminum Phosphate Hydroxide Hydrate :	**Turquoise**	3.68_x	2.91_8	6.17_7	3.44_7	**6– 214**
i	Copper Aluminum Silicate Hydroxide : Calcium	**Papagoite**	2.87_x	4.29_9	2.20_9	3.44_8	**13– 372**
o	Copper Aluminum Silicate Hydroxide Hydrate : Potassium Sodium	**Ajoite**	12.3_x	2.46_1	4.08_1	3.06_1	**35– 477**
o	Copper Aluminum Sulfate Hydroxide Hydrate :	**Cyanotrichite**	10.2_x	3.88_9	5.26_8	5.47_5	**11– 131**
o	Copper Aluminum Sulfate Hydroxide Hydrate :	**Woodwardite**	9.10_x	2.58_6	1.50_6	4.43_4	**29– 529**
	Copper Aluminum Sulfate Hydroxide Hydrate :	**Chalcoalumite**	8.92_x	8.29_x	4.24_x	4.36_9	**8– 142**
i	Copper Aluminum Sulfate Hydroxide Hydrate :	**Chalcoalumite**	8.50_x	4.25_9	4.18_3	7.90_2	**25–1430**
i	Copper Aluminum Sulfate Hydroxide : Lead	**Osarizawaite**	3.00_x	5.75_8	3.52_6	2.87_5	**15– 178**
i	Copper Antimony Arsenic Tellurium Sulfide :	**Goldfieldite**	2.97_x	1.82_6	3.64_3	1.55_3	**29– 531**
i	Copper Antimony Chloride Arsenate Hydroxide Hydrate : Calcium	**Richelsdorfite**	3.05_x	4.91_7	4.39_6	1.75_6	**35– 585**
	Copper Antimony Oxide Hydroxide :	**Partzite**	2.95_x	5.91_9	1.81_8	3.08_7	**7– 303**
i	Copper Antimony Selenide :	**Permingeatite**	3.25_x	1.99_9	1.70_8	1.15_7	**25– 263**
i	Copper Antimony Sulfide :	**Chalcostibite, syn**	3.14_x	2.99_x	3.11_9	3.01_9	**35– 413**
	Copper Antimony Sulfide :	**Chalcostibite, syn**	3.11_x	3.09_9	2.99_9	2.97_9	**24– 347**
*	Copper Antimony Sulfide :	**Famatinite, syn**	3.11_x	1.90_7	1.62_4	1.10_3	**35– 581**
*	Copper Antimony Sulfide :	**Tetrahedrite, syn**	2.98_x	1.83_4	2.58_3	1.56_3	**24–1318**
i	Copper Antimony Sulfide :	**Skinnerite, syn**	2.83_x	2.63_9	2.62_9	1.81_9	**26–1110**
	Copper Arsenate :	**Trippkeite, syn**	3.16_x	6.07_6	3.04_5	2.72_4	**31– 451**
	Copper Arsenate :	**Lammerite**	2.89_x	2.52_9	3.06_8	3.00_8	**35– 497**
	Copper Arsenate Carbonate Hydroxide Hydrate : Calcium	**Tyrolite**	28.0_x	14.1_8	2.98_8	2.70_8	**11– 348**
	Copper Arsenate Hydrate :	**Mixite**	12.1_x	2.46_9	4.48_8	3.57_8	**13– 413**
o	Copper Arsenate Hydrate :	**Lindackerite**	10.2_x	3.19_8	3.95_6	3.08_6	**11– 166**
	Copper Arsenate Hydroxide :	**Cornubite**	4.72_x	2.56_x	2.49_x	2.69_9	**12– 288**
	Copper Arsenate Hydroxide :	**Clinoclase**	3.59_x	3.14_3	7.21_2	3.06_2	**12– 297**
	Copper Arsenate Hydroxide :	**Olivenite**	2.98_x	4.82_9	5.91_7	2.47_7	**4– 657**
i	Copper Arsenate Hydroxide : Calcium	**Conichalcite**	2.84_x	3.12_9	2.59_5	2.55_4	**11– 306**
	Copper Arsenate Hydroxide Hydrate :	**Strashimirite**	18.7_x	2.86_x	8.97_9	3.13_9	**21– 289**
	Copper Arsenate Hydroxide Hydrate :	**Euchroite**	5.34_x	2.83_9	7.37_8	2.64_8	**4– 222**
o	Copper Arsenate Hydroxide Hydrate :	**Arhbarite**	4.57_x	4.51_9	3.72_6	2.60_5	**35– 562**
i	Copper Arsenate Hydroxide Hydrate :	**Cornwallite**	3.22_x	3.53_9	3.10_9	2.41_9	**12– 287**
	Copper Arsenate Hydroxide : Lead	**Duftite**	3.26_x	2.85_8	2.65_8	2.57_6	**14– 169**
o	Copper Arsenate Sulfate :	**Unnamed mineral**	10.7_x	2.59_x	4.57_8	4.04_7	**29– 532**
i	Copper Arsenate Sulfate Hydroxide Hydrate :	**Parnauite**	14.3_x	4.52_6	10.4_3	4.00_2	**29– 533**
c	Copper Arsenic Antimony Sulfide :	**Luzonite, antimonian**	3.07_x	1.88_3	1.61_2	1.60_1	**25– 285**
	Copper Arsenic Selenide :	**Mgriite**	3.18_x	1.95_x	1.67_5	1.27_4	**35– 675**
*	Copper Arsenic Sulfide :	**Enargite, syn**	3.22_x	3.21_x	2.85_8	1.86_7	**35– 775**
c	Copper Arsenic Sulfide :	**Lautite**	3.11_x	3.09_9	1.91_4	2.98_2	**25–1179**
	Copper Arsenic Sulfide :	**Lautite**	3.10_x	1.90_8	1.61_6	1.23_5	**12– 738**
	Copper Arsenic Sulfide :	**Luzonite, syn**	3.05_x	1.86_9	1.59_7	1.58_6	**10– 450**
o	Copper Arsenic Sulfide :	**Arsenosulvanite**	3.04_x	1.87_x	1.59_5	1.08_3	**25– 265**
	Copper Arsenic Sulfide :	**Sinnerite, syn**	3.02_x	1.85_8	1.58_7	2.61_4	**25– 264**
	Copper Arsenic Sulfide : Silver	**Pearceite, cuprian**	2.97_x	2.80_9	2.47_6	2.30_6	**8– 130**
	Copper Arsenic Tin Vanadium Sulfide :	**Colusite**	3.07_x	1.88_6	1.60_4	1.22_3	**9– 10**
i	Copper Arsenic Vanadium Sulfide :	**Arsenosulvanite, syn**	3.04_x	1.86_7	1.59_5	1.32_2	**35–1017**
i	Copper Arsenide :	**Paxite**	3.16_x	3.63_8	2.77_7	2.62_7	**15– 261**
	Copper Arsenide :	**Koutekite, syn**	2.08_x	2.02_x	1.99_x	1.15_9	**13– 581**
	Copper Arsenide :	**Metadomeykite**	2.08_x	2.02_x	1.45_5	1.19_5	**14– 454**
o	Copper Arsenide :	**Metadomeykite, syn**	2.05_x	2.00_x	2.34_8	1.43_9	**2–1251**
	Copper Arsenide :	**Domeykite**	2.05_x	1.89_7	1.97_5	1.31_5	**9– 333**
	Copper Arsenide :	**Algodonite**	1.99_x	2.11_4	2.25_2	1.30_2	**9– 429**
*	Copper Arsenide Sulfide :	**Enargite, syn**	1.73_x	3.07_x	2.84_8	3.21_8	**35– 580**
	Copper Bismuth Arsenate Hydroxide Hydrate :	**Mixite**	12.0_x	2.46_9	3.57_8	2.95_7	**13– 414**
	Copper Bismuth Sulfide :	**Hodrushite**	3.10_x	3.62_8	2.72_8	3.22_7	**25– 267**
i	Copper Bismuth Sulfide :	**Cuprobismutite, syn**	3.08_x	2.72_6	3.62_5	3.22_5	**29– 536**
	Copper Bismuth Sulfide :	**Emplectite**	3.05_x	3.23_9	3.13_7	7.38_5	**10– 474**
	Copper Bismuth Sulfide :	**Wittichenite**	2.85_x	3.08_8	4.55_4	2.66_4	**9– 488**
i	Copper Bismuth Sulfide : Lead Silver	**Berryite**	3.51_x	2.91_x	3.50_9	2.88_7	**19– 703**
	Copper Bismuth Sulfide : Lead Silver	**Berryite**	3.47_x	2.89_8	2.80_7	2.18_4	**19– 702**
o	Copper Bismuth Sulfide : Silver	**Unnamed mineral**	3.48_x	2.83_9	3.61_6	2.96_5	**22–1325**
i	Copper Bismuth Vanadium Oxide :	**Namibite**	3.02_x	3.57_8	5.58_7	2.67_6	**35– 711**
	Copper Boron Chloride Hydroxide :	**Bandylite**	5.59_x	3.08_8	2.54_8	1.95_7	**12– 631**
	Copper Cadmium Tin Sulfide :	**Cernyite**	3.15_x	1.94_5	1.93_5	1.12_5	**29– 537**

in this group.

							File No.
i	Copper Carbonate Hydrate : Sodium	Chalconatronite, syn	6.90_x	3.68_9	4.18_8	5.18_7	22–1458
*	Copper Carbonate Hydroxide :	Azurite	3.52_x	2.22_7	5.15_6	3.67_5	11– 682
i	Copper Carbonate Hydroxide :	Malachite, syn	2.86_x	3.69_9	5.06_8	5.99_6	10– 399
	Copper Carbonate Hydroxide : Cobalt	Kolwezite	3.70_x	6.04_8	5.08_8	2.59_8	29–1416
	Copper Carbonate Hydroxide : Zinc	Aurichalcite	6.78_x	2.61_8	3.68_7	2.89_4	17– 743
i	Copper Carbonate Sulfate Hydroxide Hydrate :	Nakauriite	7.31_x	3.65_2	2.37_2	1.91_2	29– 538
*	Copper Chloride :	Tolbachite	5.76_x	2.92_4	3.45_3	2.37_1	35– 690
*	Copper Chloride :	Nantokite, syn	3.13_x	1.92_6	1.63_3	1.24_1	6– 344
	Copper Chloride Arsenate Hydrate : Sodium Calcium	Lavendulan	9.77_x	3.11_7	4.87_5	7.01_4	31–1280
	Copper Chloride Arsenite Hydroxide : Manganese	Magnussonite	2.85_x	3.13_3	2.47_3	1.74_2	10– 407
*	Copper Chloride Hydrate :	Eriochalcite, syn	5.47_x	2.64_8	4.05_6	3.09_4	33– 451
*	Copper Chloride Hydrate : Potassium	Mitscherlichite, syn	2.64_x	2.71_x	5.42_7	3.16_5	23– 478
	Copper Chloride Hydroxide :	Botallackite	5.66_x	2.40_8	2.57_7	2.84_4	8– 88
i	Copper Chloride Hydroxide :	Atacamite	5.48_x	5.03_7	2.28_7	2.76_6	25– 269
i	Copper Chloride Hydroxide :	Paratacamite, syn	5.44_x	2.27_8	5.50_7	2.76_6	25–1427
	Copper Chloride Hydroxide Hydrate :	Calumetite	7.50_x	2.48_8	3.02_6	3.76_5	15– 669
	Copper Chloride Hydroxide Hydrate :	Anthonyite	5.84_x	4.14_7	3.99_6	3.44_6	15– 670
	Copper Chloride Hydroxide Hydrate :	Claringbullite	5.75_x	2.70_x	2.45_9	4.89_8	29– 539
i	Copper Chloride Hydroxide Hydrate : Lead	Pseudoboleite	4.43_x	3.83_x	2.71_x	2.33_7	22– 470
i	Copper Chloride Hydroxide Hydrate : Lead Silver	Boleite	4.42_x	3.82_8	2.70_6	2.55_4	27–1206
	Copper Chloride Hydroxide : Lead	Diaboleite, syn	5.50_x	2.28_x	3.28_9	2.57_9	21– 468
	Copper Chloride Nitrate Hydroxide Hydrate :	Buttgenbachite	7.95_x	13.7_x	2.30_x	2.75_9	8– 136
c	Copper Chloride Nitrate Hydroxide Hydrate :	Buttgenbachite	7.88_x	13.6_x	2.74_3	5.16_3	34– 181
	Copper Chloride Phosphate Hydrate : Sodium Calcium	Sampleite	9.60_x	3.04_x	4.30_8	1.71_8	11– 349
	Copper Chloride Sulfate Hydroxide Hydrate :	Connellite	8.00_x	13.7_x	2.75_x	2.29_x	8– 135
c	Copper Chloride Sulfate Hydroxide Hydrate :	Connellite	7.89_x	13.7_8	2.73_4	2.28_4	35– 538
*	Copper Chloride Sulfate : Potassium	Chlorothionite	3.04_x	2.19_7	2.85_4	5.69_3	29– 998
	Copper Chromium Fluoride Oxide Silicate Hydrate : Lead	Iranite	3.60_x	3.49_x	3.28_x	3.18_x	15– 683
	Copper Chromium Oxide :	Mcconnellite, syn	2.47_x	1.65_5	2.85_4	2.21_4	26–1113
c	Copper Chromium Oxide Phosphate Hydroxide : Lead	Vauquelinite	3.29_x	4.73_6	2.89_5	2.77_4	27– 270
	Copper Cobalt Nickel Sulfide :	Fletcherite	1.68_x	1.83_8	2.87_6	2.39_6	29– 540
o	Copper Cobalt Platinum Sulfide :	Carrollite, platinian	2.44_x	1.87_9	5.71_8	3.06_8	29– 541
i	Copper Cobalt Sulfide :	Carrollite	2.86_x	1.67_8	1.83_6	2.37_5	9– 425
i	Copper Gallium Sulfide :	Gallite, syn	3.06_x	1.87_8	1.61_6	1.89_5	25– 279
c	Copper Gold :	Tetra-auricupride, syn	2.23_x	1.98_3	3.67_3	2.80_2	25–1220
	Copper Gold Lead Tellurium :	Bilibinskite	2.37_x	2.05_7	1.45_6	1.23_8	29– 544
	Copper Hydroxide :	Spertiniite	2.63_x	3.73_9	5.29_8	2.27_7	35– 505
i	Copper Indium Sulfide :	Roquesite, syn	3.20_x	1.96_3	1.67_1	4.95_1	27– 159
i	Copper Iodate Hydrate :	Bellingerite	3.72_x	3.35_9	3.17_9	3.82_7	19– 393
i	Copper Iodate Hydroxide :	Salesite	4.37_x	3.66_7	2.39_6	1.79_6	22– 236
i	Copper Iodate Hydroxide :	Salesite	3.66_x	2.64_4	1.83_4	2.85_3	19– 391
*	Copper Iodide :	Marshite, syn	3.49_x	3.03_x	2.14_6	1.82_3	6– 246
o	Copper Iridium Platinum Sulfide :	Malanite	2.50_x	1.76_x	5.86_8	3.00_7	29– 552
o	Copper Iridium Sulfide :	Xingzhongite	3.02_8	1.77_7	5.99_6	1.21_x	29– 551
o	Copper Iron Aluminum Sulfate Hydroxide : Lead	Beaverite	5.85_x	3.03_x	2.28_5	3.60_4	17– 476
i	Copper Iron Arsenate Hydroxide Hydrate :	Chenevixite	3.56_x	2.55_7	3.82_5	2.99_5	29– 553
	Copper Iron Arsenate Phosphate Hydroxide Hydrate :	Arthurite	4.28_x	4.81_x	6.97_x	10.1_8	16– 397
	Copper Iron Arsenic Selenium Sulfide :	Chameanite	3.19_x	1.95_9	1.67_8	1.13_7	35– 524
	Copper Iron Arsenic Sulfide :	Tennantite	2.94_x	1.80_8	1.54_5	2.55_3	11– 102
	Copper Iron Germanium Arsenic Sulfide :	Renierite	3.06_x	1.87_8	1.60_6	2.65_3	9– 424
	Copper Iron Germanium Sulfide :	Briartite, syn	3.06_x	1.88_x	1.87_x	1.60_x	25– 282
	Copper Iron Germanium Sulfide :	Briartite, syn	1.90_x	1.62_8	1.89_6	1.61_6	30– 481
i	Copper Iron Lead Bismuth Sulfide :	Eclarite	3.41_x	2.01_8	2.89_7	3.01_6	35– 627
	Copper Iron Lead Bismuth Sulfide :	Miharaite	3.03_x	3.00_7	1.94_7	2.18_5	33– 461
	Copper Iron Lead Cadmium Sulfide :	Shadlunite	3.29_x	1.93_9	3.84_4	2.11_4	25–1426
	Copper Iron Lead Gold Tellurium :	Bogdanovite, ferroan	2.36_x	2.05_6	1.45_6	1.23_8	34–1302
i	Copper Iron Lead Sulfide :	Betekhtinite	2.94_x	1.83_9	3.08_8	2.35_7	25–1223
	Copper Iron Magnesium Aluminum Sulfide Hydroxide :	Valleriite	11.4_x	5.71_x	3.27_6	3.80_5	29– 554
i	Copper Iron Manganese Arsenite Arsenate Silicate Hydroxide :	Dixenite	2.93_x	3.44_4	2.97_4	3.91_3	35– 520
	Copper Iron Manganese Lead Sulfide :	Manganese-shadlunite	3.23_x	1.89_9	1.10_4	3.08_3	25–1425
i	Copper Iron Mercury Sulfide :	Gortdrumite	4.58_x	3.38_7	2.88_5	2.78_5	34– 184
	Copper Iron Nickel Arsenide Sulfide :	Orcelite	1.99_x	1.93_x	2.14_6	1.76_6	35– 493
	Copper Iron Nickel Chloride Sulfide : Potassium	Djerfisherite	1.84_x	3.33_7	3.17_7	3.03_7	25– 635
o	Copper Iron Nickel Chloride Sulfide : Thallium	Thalfenisite	2.96_x	3.42_9	3.24_7	1.81_7	33–1401
	Copper Iron Nickel Iridium Sulfide :	Unnamed mineral	3.33_x	1.75_x	2.98_8	1.92_8	29– 555
i	Copper Iron Nickel Sulfide :	Villamaninite	2.85_x	1.72_4	2.55_3	2.33_3	29– 556
	Copper Iron Oxide :	Cuprospinel	2.52_x	1.48_6	2.96_5	1.61_4	25– 283
	Copper Iron Oxide :	Delafossite	2.51_x	1.51_4	2.86_4	1.66_4	12– 752
	Copper Iron Phosphate Hydroxide Hydrate :	Chalcosiderite	3.77_x	3.39_7	3.02_6	3.56_4	8– 127
i	Copper Iron Platinum :	Tulameenite, syn	2.18_x	1.32_7	1.94_6	1.16_9	26– 528
	Copper Iron Selenide :	Eskebornite	1.96_x	3.19_x	1.67_8	5.53_8	14– 312
i	Copper Iron Silver Selenide Sulfide :	Geffroyite	1.93_x	3.28_9	3.15_9	2.09_6	35– 523
	Copper Iron Sulfate Hydrate :	Poitevinite	3.46_x	4.72_5	3.08_5	4.85_4	15– 120
c	Copper Iron Sulfate Hydroxide Hydrate :	Guildite	5.00_x	9.44_9	3.18_8	3.57_7	33– 464
	Copper Iron Sulfate Hydroxide Hydrate :	Cuprocopiapite	3.56_x	8.81_8	5.82_5	6.32_4	19– 394
i	Copper Iron Sulfate Hydroxide Hydrate :	Guildite	3.14_x	9.46_4	5.00_3	3.61_2	23– 217
	Copper Iron Sulfide :	Cubanite	3.22_x	1.87_8	1.75_7	1.17_5	9– 324
c	Copper Iron Sulfide :	Cubanite	3.21_x	3.49_7	3.23_5	1.86_5	24– 213
i	Copper Iron Sulfide :	Nukundamite	3.14_x	2.83_7	1.89_6	1.85_6	34–1409
o	Copper Iron Sulfide :	Idaite, syn	3.14_x	2.82_x	1.89_x	1.85_x	13– 161
i	Copper Iron Sulfide :	Nukundamite, syn	3.13_x	2.82_8	1.89_7	1.85_7	16– 159
	Copper Iron Sulfide :	Mooihoekite, syn	3.07_x	1.89_8	1.60_6	1.08_6	25– 286
	Copper Iron Sulfide :	Haycockite	3.07_x	1.88_8	1.89_6	1.61_6	25– 289
	Copper Iron Sulfide :	Talnakhite	3.06_x	1.87_9	1.60_7	1.08_6	25– 287
*	Copper Iron Sulfide :	Chalcopyrite	3.04_x	1.86_4	1.59_3	1.87_2	35– 752
	Copper Iron Sulfide :	Fukuchilite, syn	2.80_x	1.69_8	3.24_6	1.08_8	24– 365
	Copper Iron Sulfide :	Bornite	1.94_x	3.18_6	2.74_5	1.26_5	14– 323
c	Copper Iron Sulfide :	Bornite	1.94_x	3.17_4	2.74_4	3.31_3	34– 135
o	Copper Iron Sulfide : Potassium	Murunskite	6.52_x	2.53_8	2.90_6	1.94_5	33–1005
i	Copper Iron Sulfide : Potassium	Djerfisherite	1.83_x	2.99_7	2.37_6	10.3_5	18–1007

SSGS WELL RR-18 LINER SCALE BULK XRD

Approximate wt. %

Sample	Loellingite	Calcite
RR-18 outer band	89	11
RR-18 central band	91	9

-jh-
orig. sent
07/30/00

CalEnergy- M. Wright

Mineralogy, Approx. Wt.% [x] (or) Relative Abundance [x]

Salton Sea - scale samples from geothermal wells Sample No.	Quartz	Plagioclase	K-feldspar	Calcite	Halite	Loellingite	Magnetite	Chlorite	Illite+/-Mica	Nontronite- 15A	Smectite	*Amorphous Silica	Amorphous/ Below Detection	
Injection wells:														
Sinclair-26	1	tr					1	tr		7		MM		
Sinclair-26 black	tr				1	tr	1			2		M	M	tr sphalerite?
Elmore-101	2	2	2	1			tr	2	1		2	MM		
Production wells:														
Sinclair-10										52*			M	
Sinclair-11	1						2			36*			M	
Elmore-12	tr				tr	18				40*			M	

*The presence of amorphous silica is characterized by a broad hump in the diffraction pattern centered at about 3.90 angstroms. Apparently, the amorphous iron silicate (hisingerite?) leaves no signature on the diffractograms.

Nontronite-15A has a general formula of: $Na_{0.3} Fe_2 Si_4 O_{10} (OH)_2 . x H_2O$, and is characterized by broad peaks at: 14.3 (air-dried) to 16.4 (glycolated), 4.48, 2.61, and 1.53 angstroms.

Loellingite ($Fe As_2$) exhibits peaks at 2.61, 2.54, 2.42, 2.34, 2.21, 1.86, 1.69, and 1.64 angstroms.

*Based on laboratory nontronite sample — may not be applicable JH 07/30/00

MM = Predominant M = Major m = Minor Tr = Trace ? = Tentative Identification

EGI

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

Energy & Geoscience Institute at the University of Utah

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