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Volume 1 ; Book 1

TOMBSTONE

Mining District

Cochise County

ARIZONA

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COCHISE COUNTY, ARIZONA
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1/5/1
844017 ORDER NO: AAD81-15550
THE AMERICAN PURITAN AESTHETIC: ICONOGRAPHY IN SEVENTEENTH-CENTURY POETRY AND TOMBSTONE ART 227 PAGES.
HAIMS, LYNN MARIA (PH.D. 1981 NEW YORK UNIVERSITY).
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DESCRIPTOR CODES: 0591
INSTITUTION CODE: 0146

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DESCRIPTOR CODES: 0777
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1/5/3
445762 ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L
MINERALOGY AND PETROGRAPHY OF THE TOMBSTONE MINING DISTRICT, ARIZONA
RASOR, CHARLES A. (PH.D. 1937 THE UNIVERSITY OF ARIZONA).
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GEOLOGY
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DESCRIPTOR CODES: 0373
INSTITUTION CODE: 0009

1/5/6
124539 ORDER NO: AAD76-05837
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NEWELL, ROGER AUSTIN (PH.D. 1975 STANFORD UNIVERSITY).
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GEOLOGY
DESCRIPTOR CODES: 0372
INSTITUTION CODE: 0212

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3-9-82 TOMBSTONE AND ARIZONA

3/5/1
1080007 82-03262

A leaky reservoir model for ephemeral flow recession
Peebles, R. W.; Smith, R. E.; Yakowitz, S. J.
U. S. Dep. Inter., Off. Surf. Min. Reclam. Enforc., Washington, DC, USA; U. S. Dep. Agric., USA
Water Resources Research 17: 3, 628-636p., 1981
CODEN: WRERAQ ISSN: 0043-1397 12 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
illus., 1 table, sketch map
Latitude: N313000; N315000 Longitude: W1094500; W1101500
Descriptors: *hydrology ; rivers and streams ; models; Cochise County; ephemeral streams; streams; mathematical models; theoretical studies; reservoirs; hydrographs; floods; discharge; Arizona; United States; Walnut Gulch; Tombstone
Section Headings: 21 .(HYDROGEOLOGY AND HYDROLOGY)

3/5/2
1046860 81-28966

Schieffelinite, a new lead tellurate-sulphate from Tombstone, Arizona
Williams, S. A.
Phelps Dodge Corp., Douglas, AZ, USA
Mineral Mag. 43: 330, 771-773p., 1980
ISSN: 0026-461X 2 REFS.
Subfile: B
Country of Publ.: United Kingdom
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
illus., table
Descriptors: *Arizona; *minerals ; mineralogy; sulfates; tellurates ; schieffelinite; United States; Tombstone; crystal form; physical properties; chemical composition; description; new minerals
Section Headings: 01 .(MINERALOGY AND CRYSTALLOGRAPHY)

3/5/3
1023541 81-09872

The Tombstone District, Cochise County, Arizona
Williams, S. A.
Phelps Dodge Corp., West. Explor. Off., Douglas, AZ, USA
Mineral. Rec. 11: 4: Arizona-II, 251-256p., 1980
CODEN: MRECA7 ISSN: 0026-4628 8 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
illus., tables
Descriptors: *Arizona; *minerals ; mineralogy; miscellaneous minerals ; collecting; Cochise County; United States; mining geology; mines; history; Tombstone District; silver; ore deposits; wulfenite; molybdates; jarosite; sulfates; cuprite; oxides; halides; tellurium oxysalts; rodalquilarite
Section Headings: 01 .(MINERALOGY AND CRYSTALLOGRAPHY)

3/5/4
1017307 81-00145

A triclinic unit cell for oboyerite
Roberts, A. C.
Geol. Surv. Can., Cent. Labs. Tech. Serv. Div., Ottawa, Ont., CAN

Current research, Part B
Pap. - Geol. Surv. Can. 80-1B, 295p., 1980
CODEN: CGSPAV ISSN: 0707-2996 1 REFS.
Subfile: B
Country of Publ.: Canada
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
table
Latitude: N314000; N314000 Longitude: W1100000; W1100000
Descriptors: *Arizona; *minerals ; mineralogy; tellurates ; oboyerite; Cochise County; United States; X-ray data; waste disposal; optical properties; Tombstone; Grand Central Mine
Section Headings: 01 .(MINERALOGY AND CRYSTALLOGRAPHY)

3/5/5
937795 79-20411

The Tombstone mining district; history, geology and ore deposits
Devere, B. J., Jr.
ASARCO Inc., Tucson, Ariz., USA

Land of Cochise; southeastern Arizona
Callender, J. F.(EDITOR); Wilt, J. C.(EDITOR); Clemons, R. E.(EDITOR); James, H. L.(EDITOR)
New Mexico Geological Society (with the Arizona Geological Society), 29th field conference, Arizona, United States, Nov. 9-11, 1978
N. M. Geol. Soc., Annu. Field Conf. Guideb. 29, 315-320p., 1978
CODEN: NMGGA5 14 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL; CONFERENCE PUBLICATION Bibliographic Level: ANALYTIC
Languages: English
illus., geol. sketch map
Latitude: N323000; N325000 Longitude: W1100000; W1101000
Descriptors: *Arizona; *mineral deposits; *genesis ; economic geology; controls ; silver; structural controls; United States; Tombstone District; Cochise County; ore deposits; history; production; structure ; faults; polymetallic ores; mineral deposits, genesis
Section Headings: 27 .(ECONOMIC GEOLOGY, METALS)

3/5/6
937768 79-18705

Second day; road log from Douglas to Tucson via Bisbee, Tombstone, Charleston, Fort Huachuca and Sonoita
Keith, S. B.; Wilt, J. C.

Land of Cochise; southeastern Arizona
Callender, J. F.(EDITOR); Wilt, J. C.(EDITOR); Clemons, R. E.(EDITOR); James, H. L.(EDITOR)
New Mexico Geological Society (with the Arizona Geological Society), 29th field conference, Arizona, United States, Nov. 9-11, 1978
N. M. Geol. Soc., Annu. Field Conf. Guideb. 29, 31-76, 139-142p., 1978
CODEN: NMGGA5
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL; CONFERENCE PUBLICATION Bibliographic Level: ANALYTIC
Languages: English

illus., table, geol. sketch maps
Latitude: N312000; N321500 Longitude: W1093000; W1110000
Descriptors: *Arizona ; areal geology ; road log; Cochise County; Santa Cruz County; Pima County; United States; Douglas; Tucson; Bisbee ; Tombstone; Charleston; Fort Huachuca; Sonoita
Section Headings: 13 .(AREAL GEOLOGY, GENERAL)

3/5/7
921887 79-03463

Khinite, parakhinite, and dugganite, three new tellurates from Tombstone, Arizona
Williams, S. A.
Phelps Dodge Corp., Douglas, Ariz., USA
Am. Mineral. 63: 9-10, 1016-1019p., 1978
CODEN: AMMIAY 3 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
tables
Latitude: N313000; N315000 Longitude: W1100000; W1101500
Descriptors: *Arizona; *minerals; *crystal chemistry ; mineralogy; tellurates and tellurites ; khinite; Cochise County; parakhinite; dugganite; United States; Tombstone; new minerals; Old Guard Mine; physical properties; optical properties; mineral data; X-ray data
Section Headings: 01 .(MINERALOGY AND CRYSTALLOGRAPHY)

3/5/8
890484 78-18249

Use of the universal soil loss equation in the semiarid Southwest
Osborn, H. B.; Simanton, J. R.; Renard, K. G.
U. S. Dep. Agric., Southwest Watershed Res. Cent., Tucson, Ariz., USA

Soil erosion; prediction and control
Foster, G. R.(EDITOR)
National conference on soil erosion, West Lafayette, Indiana, United States, May 24-26, 1976
Publ: Soil Conserv. Soc. Amer.
41-49p., 1977
13 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: BOOK; CONFERENCE PUBLICATION Bibliographic Level: ANALYTIC
Languages: English
illus., tables, plates
Latitude: N311500; N370000 Longitude: W1090000; W1150000
Descriptors: *Arizona; *soils; *geomorphology ; conservation; processes ; erosion; erosion control; Southwestern U.S.; United States; soil loss equation; soil erosion; arid environment; watersheds; storms; Tombstone; Walnut Gulch; channels; water erosion; climate; mathematical methods
Section Headings: 25 .(SURFICIAL GEOLOGY, SOILS)

3/5/9
889812 78-18281

Arizona
Everett, F. D.

Mining and mineral operations in the Rocky Mountain states; a visitor guide

Publ: U. S. Gov. Print. Off.
5-15p., 1977
18 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: BOOK Bibliographic Level: ANALYTIC
Languages: English
plates, sketch map
Latitude: N311500; N350000 Longitude: W1090000; W1150000
Descriptors: *Arizona ; areal geology ; guidebook; United States; mines; mineral resources; metals; copper; Globe; Miami; gold; silver ; Superior; Green Valley; ghost towns; historical sites; Jerome; Tombstone; Oatman
Section Headings: 26 .(ECONOMIC GEOLOGY, GENERAL & MINING)

3/5/10
805802 76-32048

Exploration geology and geochemistry of the Tombstone-Charleston area, Cochise County, Arizona
Newell, R. A.
Stanford
280p., 1975
Subfile: B
Degree Level: Doctoral
Doc Type: THESIS Bibliographic Level: MONOGRAPHIC
Languages: English
Diss. Abstr. Int., Vol. 36, No. 9, p. 4353B-4354B, 1976,
Descriptors: *Arizona; *metals; *mineral exploration ; economic geology; methods; United States ; Cochise County; Tombstone; Charleston; photogeologic methods; geobotanical methods; geochemical methods; silver ; manganese; copper; Tombstone District; ore deposits; age; exploration
Section Headings: 27 .(ECONOMIC GEOLOGY, METALS)

3/5/11
785178 76-11424

Time-related changes in water quality of stock tanks of southeastern Arizona
Wallace, D. E.; Schreiber, H. A.
Southwest Watershed Res. Cent., Tucson, Ariz., USA
Hydrol. Water Resour. Ariz. Southwest 4, 144-157p., 1974
Subfile: B
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
illus., table, sketch map
Descriptors: *environmental geology; *Arizona ; observations ; water quality; stock tanks; variations; pH; trace elements; copper; cobalt; lead; manganese; iron; zinc; sodium; phosphorus; calcium; potassium ; nitrogen; United States; Walnut Gulch; Tombstone
Section Headings: 22 .(ENGINEERING & ENVIRONMENTAL GEOLOGY)

3/5/12
703369 74-08473

Interpretation; Apollo 9 Photography of Parts of Southern Arizona and Southern New Mexico
Owen, J. Robert; Shown, Lynn M.
U. S. Geol. Surv. 16 p., illus., Denver, Colorado, 1973
Subfile: B
Languages: English
Open-file Report, Features due to differences in soils or vegetation

easily discriminated on color infrared photographs, 1:650,000 of arid and semiarid regions
Descriptors: *New Mexico; *Geomorphology; *soils; *Maps; *Arizona ; Areal geology; Cartography; Surveys ; south; Otero County; Tularosa Basin; Separ; Photogeology; orbital; Apollo 9; infrared methods; United States; interpretation; regional; landform description; drainage patterns; Cochise County; Tombstone; San Simon Valley
Section Headings: 13 .(AREAL GEOLOGY, GENERAL)

3/5/13
682699 73-21976

Petrology and stratigraphy of the Epitaph Dolomite (Permian) in the Tombstone Hills, Cochise County, Arizona
Patch, Susan.
J. Sediment. Petrol. Vol. 43, No. 1, p. 107-117, illus. (incl. sketch maps), 1973
CODEN: JSEPAK
Subfile: B
Doc Type: SERIAL
Languages: English
Thickness, lithostratigraphy, nature of the allochemical material, evidence that the Epitaph Dolomite is a dolomitized facies of the Colina Limestone, lower to middle Leonardian age
Descriptors: *Arizona; *Permian; *Sedimentary rocks ; Sedimentary petrology; Carbonate rocks; United States ; Dolomite; Epitaph Dolomite; Cochise County; Tombstone Hills; petrography; stratigraphy; genesis; correlation; southeast; Leonardian
Section Headings: 06 .(PETROLOGY, SEDIMENTARY)

3/5/14
644737 72-25970

Available soil water; time-distribution in a warm season rangeland
Schreiber, H. A.; Sutter, N. G.
J. Hydrol. Vol. 15, No. 4, p. 285-300, illus., 1972
CODEN: JHYDA7
Subfile: B
Doc Type: SERIAL
Languages: English
Daily total rainfall depths translated into infiltration and subsequent evaporation, field studies in Arizona using data from 1897-1970
Descriptors: *Ground water; *Arizona; *soils ; Distribution; Water regimes; Hydrogeology ; United States; Tombstone; Storage
Section Headings: 21 .(HYDROGEOLOGY AND HYDROLOGY)

3/5/15
618907 71-61927

A geophysical study of the hydrogeology of the Walnut-Gulch experimental watershed, Tombstone, Arizona
Spangler, Daniel P.
1969
Subfile: B
Degree Level: Doctoral
Doc Type: THESIS
Languages: English
Descriptors: *Arizona; *Ground water; *Geophysical surveys ; Hydrogeology; United States ; Tombstone; Walnut Gulch experimental watershed
Section Headings: 21 .(HYDROGEOLOGY AND HYDROLOGY)

3/5/16

618107 71-61103

Petrology and stratigraphy of the Epitaph dolomite (Permian) in the Tombstone hills, Cochise county, Arizona
Patch, Susan.
1969
Subfile: B
Degree Level: Master's
Doc Type: THESIS
Languages: English
Descriptors: *Arizona; *Permian; *Sedimentary rocks ; Stratigraphy; United States; Dolomite ; Epitaph dolomite; Cochise county; Tombstone hills; Petrology
Section Headings: 12 .(STRATIGRAPHY, HISTORICAL GEOLOGY)

3/5/17
581521 71-00701

Some limitations of seismic refraction methods in geohydrological surveys of deep alluvial basins
Wallace, D. E.
Ground Water Vol. 8, No. 6, p. 8-13, illus. (incl. sketch map), 1970
CODEN: GRWAAP
Subfile: B
Doc Type: SERIAL
Languages: English
Stratigraphic and lithologic conditions which complicate data acquisition and interpretation
Descriptors: *Arizona; *ground water; *Seismic methods; *Sediments ; Hydrogeology; Interpretation; Alluvium; General ; Cochise county; Tombstone; Properties; seismic
Section Headings: 21 .(HYDROGEOLOGY AND HYDROLOGY)

3/5/18
557750 70-10158

A geophysical study of the hydrogeology of the Walnut Gulch experimental watershed, Tombstone, Arizona .abstr..
Spangler, Daniel Patrick.
Diss. Abstr. Int. Vol. 30, No. 5, p. 2264B, 1969
Subfile: B
Doc Type: SERIAL
Languages: English
Descriptors: *Arizona; *Gravity surveys; *Magnetic surveys; *Seismic surveys; *Ground water ; Tombstone; Walnut Gulch experimental watershed; hydrogeology; Resources
Section Headings: 18 .(GEOPHYSICS, SOLID EARTH)

3/5/19
552514 70-04943

Ore deposits at Tombstone, Arizona
Butler, B. S.; Wilson, Eldred D.

in Ore deposits as related to structural features (W. H. Newhouse, ed.), p. 201-203, illus. (incl. sketch map),
Hafner Publ. Co. New York-London, 1969
Subfile: B
Languages: English
Metals, structural movement along fractures, deposition at intersecting structures
Descriptors: *Arizona; *Metals; *genesis; *Mineral deposits ; Economic geology ; Tombstone; structure; structural controls

Section Headings: 26 .(ECONOMIC GEOLOGY, GENERAL & MINING)

3/5/20
549259 70-01674

The economic geology of portions of the Tombstone-Charleston district, Cochise County, Arizona, in light of 1967 silver economics
Lee, L. Courtland.
1967
Subfile: B
Degree Level: Master's
Doc Type: THESIS
Languages: English
Descriptors: *Arizona; *Silver; *Mineral economics; *Mineral deposits; *genesis ; Economic geology ; Tombstone; Charleston; Cochise County
Section Headings: 26 .(ECONOMIC GEOLOGY, GENERAL & MINING)

3/5/21
546450 70-05878-N

SOME LIMITATIONS OF SEISMIC REFRACTION METHODS IN GEOHYDROLOGICAL SURVEYS OF DEEP ALLUVIAL BASINS
WALLACE, D. E.
GROUND WATER, V. 8, NO. 6, P. 8-13 1970
Subfile: N
Descriptors: *ALLUVIAL BASIN; *ARIZONA; *DEEP ALLUVIAL BASIN; *GEOPHYSICAL SURVEYS; *GROUND WATER; *HYDROGEOLOGY; *LEVELS; *LIMITATIONS; *REFRACTION; *SEISMIC EXPLORATION; *SEISMIC REFRACTION; *SEISMIC REFRACTION SURVEY; *SEISMIC SURVEYS; *TOMBSTONE AREA

3/5/22
539498 71-08524-G

SOME LIMITATIONS OF SEISMIC REFRACTION METHODS IN GEOHYDROLOGICAL SURVEYS OF DEEP ALLUVIAL BASINS
WALLACE, D. E.
GROUND WATER, V. 8, NO. 6, P. 8-13 1970
Subfile: G
Descriptors: *ARIZONA; *DEEP ALLUVIAL BASIN; *GEOPHYSICAL SURVEYS; *SEISMIC; *SEISMIC SURVEYS; *TOMBSTONE AREA

3/5/23
527360 69-06328-G

APPLICATION OF THE GRAVITY SURVEY METHOD TO WATERSHED HYDROLOGY
SPANGLER, DANIEL P.; LIBBY, FRED J.
GROUND WATER, V. 6, NO. 6, P. 21-26 1968
Subfile: G
Descriptors: *ARIZONA; *GEOPHYSICAL SURVEYS; *GRAVITY; *GRAVITY SURVEYS; *TOMBSTONE AREA; *WALNUT GULCH WATERSHED

3/5/24
479708 68-05746-N

Application of the gravity survey method to watershed hydrology
Spangler, Daniel P.; Libby, Fred J.
Ground Water v. 6, no. 6, p. 21-26, illus., table, 1968
Subfile: N
Results are reported of a gravity survey covering 250 sq mi and including the Walnut Gulch experimental watershed at Tombstone, Ariz. Geology of the watershed is typical of the Basin and Range province, containing deep basin-fill deposits storing a large volume of ground water, and surrounded by igneous and sedimentary rocks. Concealed border faults may have a

decided effect on the hydrology. The 16 mgal gravity low over the east-central part of the watershed is interpreted as indicating about 3,200 feet of low density alluvium. Highs are associated with mountain ranges and igneous plugs. A Bouguer gravity map showing generalized geology is included.
Descriptors: *Arizona; *Gravity surveys; *Hydrogeology; *Sediments ; Geophysical surveys; gravity; Maps; Exploration methods; Alluvium ; Tombstone area; Walnut Gulch watershed; Volume

3/5/25
474065 68-02666-N

Preliminary report on the Late Quaternary geology of the San Pedro Valley, Arizona
Haynes, C. Vance

in Southern Arizona Guidebook 3--Geol. Soc. America Cordilleran Sec., 64th Ann. Mtg., Tucson, 1968
Tucson, Ariz., Arizona Geol. Soc. p. 79-96, illus., tables, 1968
Subfile: N
Late Quaternary deposits contain a Rancholabrean fauna and are inset against an older valley fill containing an Irvingtonian fauna in the upper units. The oldest units contain lacustrine deposits of Wisconsin age which were preceded by an episode of marked erosion during which a distinctive red soil was formed. From 30,000 to 12,000 B.P. lacustrine clays and marls were deposited without significant alluvial deposits. After 12,000 B.P. the lake or lakes were reduced or disappeared and streams were incised into the deposits. Black organic mat deposits may be from ponds about 10,000 to 11,000 B.P. Since then there have been at least two major cycles of erosion and deposition, and most of the lake beds were removed. The Whetstone surface may be from the lake interval, and the Tombstone surface has a red soil, of possible Sangamon age. The Arivaipa surface forms the top of the alluvial deposits.
Descriptors: *Arizona; *Geomorphology; *Quaternary ; Stratigraphy; Landform evolution ; San Pedro Valley; late Quaternary history; San Pedro River valley

3/5/26
438462 67-00401-N

Silver-bearing black calcite in western mining districts
Hewett, D. F.; Radtke, A. S.
Econ. Geology v. 62, no. 1, p. 1-21, illus., tables, 1967
Subfile: N
Descriptors: *Arizona; *Silver; *Manganese; *Mineral data; *Mineral deposits; *genesis; *Nevada; *New Mexico; *Thallium; *Utah ; Economic geology; Geochemistry; Calcite; Manganese oxides; Abundance ; Tombstone; Silver compounds; occurrence; Composition; black calcite; Argentian; United States; southwestern; Lake Valley district; Manganates; southwestern U.S.; Silver ores; Ophir; San Francisco

3/5/27
429221 67-09199-G

DIFFERENTIAL VERTICAL UPLIFT-A MAJOR FACTOR IN THE STRUCTURAL EVOLUTION OF SOUTHEAST ARIZONA
JONES, R. W.
ARIZONA GEOL. SOC. DIGEST, V. 8, P. 97-124 1966
Subfile: G
Descriptors: *ARIZONA; *BASIN AND RANGE STRUCTURE; *MECHANICS; *MULE MOUNTAINS; *SOUTHEASTERN; *SOUTHEAST; *TECTONICS; *TOMBSTONE HILLS; *VERTICAL TECTONICS

3/5/28
420253 66-12087-N

Permian fusulinids of the type Earp Formation, Tombstone, Arizona .abs..
Dubin, David J.; Bryant, Donald L.
Geol. Soc. America Spec. Paper 87 p. 200, 1966
Subfile: N
Descriptors: *Foraminifera; *Permian; *Arizona ; Paleontology ; Earp Formation; fusulinids; Tombstone area

3/5/29
414968 66-03749-N

General geology and some structural features of the Courtland-Gleeson area, Cochise County, Arizona
McRae, Otis M.
Soc. Mining Engineers Trans. v. 235, no. 2, p. 133-138, illus., table, geol. map, 1966
Subfile: N
The Courtland-Gleeson area is about 15 mi east of Tombstone. Exposed rocks range from Precambrian to Quaternary; a summary description is given in a table. All rocks as old as early Tertiary have been involved in either tilting, normal faulting, high angle reverse faulting, imbricate thrusting, or folding and overfolding. The major structure is the Dragoon thrust, but four other thrusts and two gravity slide faults are described also. Following early Tertiary quartz latite emplacement, northeast-southwest compressional forces caused thrust plates containing lower Paleozoic rocks to override Cretaceous rocks. Later normal faulting dislocated thrust plates, and large rock masses slid eastward by gravity.
Descriptors: *Arizona; *Faults ; Structural geology; Stratigraphy; Maps; Normal; Overthrust ; Courtland-Gleeson area; table; Geologic

?

REF:

"BIBLIOGRAPHY OF GEOLOGY & MINERAL RESOURCES OF ARIZONA"
BULLETIN 173 (1965) PERIOD 1848-1964
BY - RICHARD T MOORE & ELDRED D. WILSON
UNIV of ARIZONA PRESS. TUSCON, ARIZONA

NOTE #1 - THIS BULLETIN IS FREE TO ARIZONA RESIDENTS AS NOTED IN EXHIBIT #A - ATTACHED. IT IS SUGGESTED THAT THIS BULLETIN 173 BE OBTAINED IF NOT IN HAND AT THIS TIME.

NOTE #2 - REF'S TO TOMBSTONE DISTRICT IN BULLETIN 173 ARE LISTED BELOW AND THOSE AVAILABLE AT THE - ARIZONA BUREAU OF MINES, STATE FAIRGROUNDS MINERAL BLD'G, 19th AVE & McDOWELL, PHOENIX, ARIZONA - ARE AVAILABLE FOR LOAN COPIES ARE LEGENED SUCH AS: BLAKE, W.P. (8) (40) AND SUCH AS BLAKE, W.P., 7, 34 WILL HAVE TO BE RESEARCHED AT OTHER SOURCES SUCH AS,

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(2) ARIZONA ROOM, A.S.U. LIBRARY, TEMPE, ARIZONA
(3) ARIZONA GEO. SECTION, ~~ARIZONA STAT~~ UNIV. of ARIZ., TUSCON
(4). U.S. BUREAU of MINES
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TUSSON, ARIZONA (MR. SOULE - DIRECTOR)

BLAKE, W.P., 7, (8), 34, (40)
BRISMADE, R.B., 4
BUTLER, B.S., 8, (9), (13), 16
CHURCH, J.A., 1, (2).
CLARKE, F.W.; DEVERE, J.; GILLULY, J., 10
GOODALE, C.W., (1), 2.
HILLEBRAND, W.F., 1
HOLLYDAY, E.F.; LAKES, A., 2
MOSES, A.J., 1, 2, 3, 4.
NEEDHAM, A.B.; RANSOME, F.L., (26)
RASOR, C.A., (1), 2, (3), 4
SHAW, S.F., 2
STAUNTON, W.F., 2
TENNEY, J.B., 11

CON'T

EF: (8)

"THE GEOLOGY & VEINS OF TOMBSTONE, ARIZONA."
BY - WILLIAM P. BLAKE
EXTRACTS FROM PAGES 334 & 335 IN THE,
"AMERICAN INSTITUTE OF MINING ENGINEERS, VOL X, 1882.

POSSIBLE USE AS CORRELATION ARE FOLLOWING NOTES DEALING MOSTLY WITH TOUGHNUT, GOODENOUGH, WAY UP, VIZINA AND CONTENTION MINES:

- NOTE #1 - CHIEF ORE BEARING STRATAS ARE DARK BLACK OR BLUE LIMESTONES AND BEDS OF DARK ARGILLACEOUS SHALE ALTERNATING WITH BLACK SILICIOUS SHALES. WHOLE SERIES OF BEDS HAVE BEEN THROWN INTO FOLDS WITH STEEPEST AND SHARPEST FOLDS TO NORTHWEST.
- NOTE #2 - THE CHIEF FISSURE AND ORE BEARING VEINS OF THE DISTRICT TRAVERSES THE CONTACT LINES THAT THE INTRUSIVE DIKES HAVE CUT THRU THE OLDER FORMATIONS AND IN SEVERAL CASES ARE NOTICEABLE & MARKED BY THE IRON RUST LINES OF DISCOLORATION OF SURFACE SOIL.
- NOTE #3 - MOST DIKES HAVE DISTINCT VERTICAL LAMINATED STRUCTURE
- NOTE #4 - CONSIDERABLE AMOUNT OF MINERALIZATION OF THE DIKES BY IRON PYRITES DISSEMINATED IRREGURARY IN ITS SUBSTANCE IN CUBICAL CRYSTALS, MANY OF WHICH HAVE DISSOLVED OUT AND LEFT CAVATIES ONLY TO INDICATE THEIR FORMER PRESENCE, MAKING IN SOME PLACES A SPONGY MASS OF PORPHORY OR QUARTZ.
- NOTE #5 - EXTENSIVE DECOMPOSITION OF SOME PORPHORYS UP TO DEPTHS OF 300' FROM SURFACE RESULTED IN THE FORMATION OF WHITE CLAY & KAOLIN.
- NOTE #6 - SILVER OCCURANCE CHIEFLY AS CLORIDE.
- NOTE #7 - OCCURANCE OF GOLD IN THIN SUB-CRYSTALLINE FLAKES & SCALES IN & ALONG THIN SEAMS & CRACKS OF THE DIORITIC PORPHORY CONTAINING FINELY DISSEMINATED HORNBLENDE.
- NOTE #8 - IN THE WESTWARD PROLONGATION OF THE WESTSIDE LODE OR VERTICAL ORE BEARING FISSURE, THE CONTIGUITY OF THE BEDDED DEPOSITS TO THE VERTICAL FISSURES & DIKES, AND THE OCCURANCE OF BEDDED ORES WHERE THE DIKES INTERSECT LIMESTONE STRATA LEAD TO THE OPINION THAT THE METALLIZATION OF THE DISTRICT IS DUE TO THE IGNEOUS INTRUSIONS AND THAT THESE

CON'T

REF. #(8) CON'T NOTE #8-

INTRUSIONS, WITH THE ACCOMPANYING IMPREGNATIONS AND RAMIFYING VEINLETS OF QUARTZ, ARE THE TRUE LODES AND "LEADS" THAT MAY BE FOLLOWED IN SEARCH OF ORE.

REF: (40)

"TOMBSTONE AND ITS MINES"
BY - WILLIAM F. BLAKE, DIRECTOR, ARIZONA SCHOOL OF MINES.
FROM - AMERICAN INST. OF MINING ENGINEERS, VOL. XXXIV, 1904.
PAGES 668 - 670.

NOTE #1 - THE WESTSIDE VEIN HAS BEEN EXTENSIVELY WORKED & HAS PRODUCED A LARGE AMOUNT OF ORE, NOT ONLY FROM THE LATERAL DEPOSITS IN LIMESTONE, KNOWN AS "FLATS" OR "BLANKET DEPOSITS," BUT FROM ORE BODIES ON THE PLANE OF THE VEIN TO A DEPTH OF ABOUT 500', OR TO THE WATER LEVEL.

NOTE #2 - IT IS ASCERTAINED THAT THE LATERAL DEPOSITS, "FLATS" EXTENDING FROM THE PLANE OF THE VEIN, OR LODE, AND GENERALLY INTO THE BEDS OF LIMESTONE, FOLLOW THE CRESTS OF THE ANTICLINICAL FOLDS RATHER THAN THE SYNCLINES OR OTHER PORTIONS OF THE BEDS.

NOTE #3 - SEVERAL SUCH ORE-LADEN ANTICLINAL "FOLDS" OR "SADDLES" OR "ROLLS" AS THEY ARE LOCALLY KNOWN, HAVE BEEN DEVELOPED & QUANITIES OF VALUABLE ORE HAVE BEEN TAKEN FROM THEM.

NOTE #4 - THE BLANKET-DEPOSITS HAVE GREAT EXTENSION COMPARED TO THEIR WIDTH, AND FOLLOW THE CRESTS OF THE FOLDS IN THEIR DOWNWARD PITCH AWAY FROM THE INTERSECTING LODES. SEVERAL SUCH DEPOSITS HAVE BEEN FOLLOWED FROM THE WEST SIDE VEIN NEARLY TO THE WATER-LEVEL.

NOTE #5 - THE BLANKET DEPOSITS APPEAR TO HAVE BEEN REINFORCED, OR ENRICHED, BY EACH SUCCESSIVE CREVICE, OR VEIN, CROSSING THEM OR THE LIMESTONE ANTICLINES.

NOTE #6 - THE FORMER OBSERVATION & STATEMENT, THAT THE HEAVIEST OR LARGER ORE-BODIES ARE FOUND ON THE LOWER OR DOWN-HILL SIDE OF INTERSECTION OF THE PLICATED ROCKS WITH THE CREVICES OR LODES, IS SUSTAINED & EXEMPLIFIED

NOTE #7 - MUCH LIGHT HAS BEEN THROWN ON THE QUESTION OF THE ORGINATION OF THE MANGANIFEROUS ORES OF THE

CON'T

REF: #40 CON'T NOTE #7-

LUCKY CUSS, THE LUCK-SURE, THE KNOXVILLE AND OTHER MINES, BY THE DISCOVERY OF A MASS OF MANGANESE-SULPHIDE, THE MINERAL SPECIES ~~ALBA~~ ALABANDITE, IN THE LIMESTONE UPON ONE OF THE LOWER LEVELS OF THE LUCKY CUSS MINE, NEAR THE CONTACT OF THE LIMESTONE WITH THE GRANIDIORITE. THERE IS LITTLE REASON TO DOUBT THAT INCLUDED MASSES OR KIDNEYS OF ALABANDITE IN THE LIMESTONE, ARE THE SOURCE BY DECOMPOSITION OR PRECIPITATION, OF THE MAN--GANIFEROUS ORES OF THE PIPES OR CHIMNEYS SO COMMON FROM THE SURFACE DOWNWARDS. THESE DEPOSITS, BY THE FORM & RELATION TO THE LIMESTONE, INDICATE THEIR DEPOSITION FROM SOLUTIONS FLOWING DOWNWARDS. THE ALTERNATION OF THE SULPHIDE BY OXIDATION, WITH THE FORMATION OF MANGANESE SULPHATE SOLUTIONS, WOULD GIVE THE CONDITIONS REQUISITE. SUCH SOLUTIONS WOULD FOLLOW THE CREVICES DOWNWARDS, ENLARGING THEM BY SOLUTION OF THE WALLS, AT THE SAME TIME DEPOSITING CRUSTS & MASSES OF MANGANESE OXIDE BY REPLACEMENT, WHILE CALCIUM SULPHATE WOULD FLOW AWAY. HOWEVER WE FIND CONSIDERABLE QUANITIES OF CALCITE IN ASSOCIATION, WHICH IS INDICATIVE OF ITS FORMATION AS ONE PRODUCT OF THE INTERCHANGE.

THIS EXPLANATION OF THE FORMATION OF THE MANGANESE OXIDE ORES ALSO EXPLAINS THE PECULIAR, IRREGULAR FORMS IN WHICH THEY ARE FOUND. THE OCCUPY IRREGULAR CREVICES WITHOUT THE TABULAR FORM OF THE FILLING OF REGULAR FISSURES. THEY ARE OFTEN PIPELIKE, AS SHOWN IN SECTIONS OF THE LUCKY CUSS & OF THE KNOXVILLE MINE.

THE FORMATION OF MANGANESE OXIDES FROM MANGANESE SULPHIDE, & OF OXIDIZED IRON-ORES FROM IRON SULPHIDE, ARE ANALOGOUS.

REF: (26) U.S. DEPT of INTERIOR - FEB. 1956 PUBLICATION
BUREAU of MINES, REPORT of INVESTIGATIONS 5188
"INVESTIGATION OF TOMBSTONE DISTRICT MANGANESE DEPOSITS"
COCHISE COUNTY, ARIZONA.
BY - A.B. NEEDHAM & W R STORMS

NOTE #1 - NOT APPLICABLE TO CHARLESTON OPERATION - CWT.

REF'S (9) & (13)

UNIV. OF ARIZONA BULLETIN, VOL. IX, No. 4
ARIZONA BUREAU OF MINES, GEOLOGICAL SERIES No. 12, BULL #145
"SOME ARIZONA ORE DEPOSITS" OCT. 1, 1938.
PAGES 104 TO 109
"STRUCTURAL CONTROL OF THE ORE DEPOSITS OF TOMBSTONE, ARIZONA."
BY - B. S. BUTLER & ELDRED D. WILSON.
— NOTE #1 - EXTRACTS ONLY FROM PAPERS BY RANSOME 1906-1911, & GILLULY 1936-1937.
(NOT APPLICABLE TO CHARLESTON OPERATION - CWT)

REF: (26) ADDED.
"CONTRIBUTIONS TO ECONOMIC GEOLOGY - 1919"
BY - F. L. RANSOME & E. F. BUCHARD
U.S.G.S. BULLETIN 710
— NOTE #1 - ARIZONA MANGANESE REFERENCES ONLY - CWT.

REF: (1)

AMERICAN INSTITUTE OF MINING ENGINEERS, VOL. XVII, 1888-1889
"OCCURANCE OF ARGENTIFEROUS MANGANESE ORE AT TOMBSTONE, ARIZONA." BY - CHARLES W. GOODALE.
— NOTE #1 - EARLY MANGANESE REFERENCES - CWT.

REF: (2)

AMER. INSTITUTE OF MINING ENGINEERS, VOL. XXXIII, 1902.
PAGES 3 TO 37
"THE TOMBSTONE, ARIZONA MINING DISTRICT."
BY - J. A. CHURCH.
— NOTE #1 - BEST ACCEPTABLE FORMATION STUDY SO FAR - CWT - 8-16-67
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REF: (3)

ECONOMIC GEOLOGY - VOL. XXXIV, NOV. 1939, No. 7
"MANGANESE MINERALIZATION AT TOMBSTONE, ARIZONA."
BY - CHARLES A. RASOR.
— NOTE #1 - ORE TREATMENT STUDIES THAT COULD POSSIBLY BE UTILIZED - CWT.
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AVAILABLE FOR STUDY AT PHOENIX CITY LIBRARY, ARIZONA, ROOM, CENTRAL & McDOWELL.

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553 B.476G ARIZ. "GEOLOGY & ORE DEPOSITS OF THE TOMBSTONE DISTRICT, ARIZONA." BY- B.S. BUTLER; E.D. WILSON; C.A. RASOR. - 1938. ARIZONA BUREAU OF MINES, GEOLOGICAL SERIES No. 10, BULL. 143 VOL. IX, No. 1 & SUPPLEMENT MAP SECTIONS.

557 R.174g.E. ARIZ. "GEOLOGY & ORE DEPOSITS OF THE BISBEE QUADRANGLE" BY - FREDRICK L. RANSOME - 1904.

ALSO AVAILABLE FOR STUDY FROM MAIN FLOOR AT PHX. LIBRARY.

557 G.419g "GENERAL GEOLOGY OF CENTRAL COCHISE COUNTY, ARIZONA." BY - JAMES GILLULY WITH CORRELATION SECTIONS BY, A.R. PALMER; JAMES S. WILLIAMS, J.B. REESIDE JR. GEOLOGICAL SURVEY PAPER 281

- NOTE #1 - POCKET PLATE MAPS INCLUDED ARE OF INTEREST TO CHARLESTON OPERATION AS REGIONAL INFORMATION - CWA.
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SUMMARY TO AUG. 17, 1967

#1. SCOPE OF FUTURE WORK DEPENDS LARGELY ON RESULTS OF CORE TEST #1 AT CHARLESTON PLANT SITE LOCATION.

#2. COPPER IS EVIDENTLY MAIN MASS OBJECTIVE - BUT - IF VALUES IN OTHER MINERALS SHOW AT PROJECTED INTERSECTS WITH LIMESTONE STRATAS - THAT A CLOSE LOOK BE TAKEN AT THE SURFACE INDICATIONS OF CLAY, KAOLIN, CREST SECTIONS WITH EXTENSIVE HORNBLENDE, AND THE DISTINCTIVE IRON OXIDE SECTIONS IN THE NORTHEAST SECTOR OF THE PROJECT BEFORE LOCATION OF FUTURE CORE DRILLING LOCATIONS ARE DECIDED UPON.

#3. THAT THE ANALYSIS OF PAST & PRESENT SAMPLING BE CHARTED ON A MASTER REGIONAL MAP OF AREA

#4. THAT A FULLY QUALIFIED ASSAY FIRM BE USED TO PROCESS ANY FUTURE SAMPLING BY QUARTERING.

#5. THAT REVIEW BE MADE OF CURRENT ORE PROCESSING DATA.

#6. THAT A CLOSE LOOK BE TAKEN AT THE PROSPECT IN THE DRAGOON MOUNTAINS THAT COSGROVE SELECTED SAMPLES FROM.

ARIZONA BUREAU OF MINES
Publication List Revisions
July 7, 1965

EXHIBIT "A"

596

Additions

Maps:

Map of Arizona Showing Principal Power and Transportation Facilities .... $ .50

Bulletin:

Bulletin 168, Gold Placers and Placering in Arizona .... .75 *

Bulletin 173, Bibliography of the Geology and Mineral Resources of Arizona .... 3.00 *

Bulletin 174, Guidebook I - Highways of Arizona, U. S. Highway 666 .... .50 *

Bulletin Loan Service:

Bulletin 157 - Field Tests for the Common Metals.

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* Free to Arizona residents

Bulletins

The Arizona Bureau of Mines has the following bulletins available for free distribution to residents of Arizona. Nonresidents may purchase bulletins at the prices quoted, which include mailing charges:

127-Manganese Ore Deposits; by E. D. Wilson and G. M. Butler	$0.30
140-Arizona Metal Production; by H. J. Elsing and R. E. Heineman	.25
148-Tungsten Deposits of Arizona; by E. D. Wilson	.25
155-Arizona Nonmetallics; by E. D. Wilson and G. H. Roseveare	.25
164-Exploration and Development of Small Mines; by H. E. Krumlauf	.25
165-One Hundred Arizona Minerals; by R. T. Moore	.30
168-Gold Placers and Placering in Arizona	.75
169-The Mineral Industries of Arizona	.25
170-Maps, with special reference to the Geologic and Mineral Maps of Arizona; by J. D. Forrester, and R. T. Moore	.25
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120-Gold and Copper Deposits near Payson, Arizona.
123-Geology and Ore Deposits of the Courtland-Gleeson Region, Arizona.
126-Asbestos Deposits of Arizona.
130-Petroleum.
134-Geology and Mineral Deposits of Southern Yuma County.
138-Treating Gold Ores.
139-Some Facts about Ore Deposits.
141-Geology and Ore Deposits of the Ajo Quadrangle, Pima County.
143-Geology and Ore Deposits of the Tombstone District, Arizona.
144-Geology and Ore Deposits of the Mammoth Mining Camp Area, Pinal County.
146-Bibliography of the Geology and Mineral Resources of Arizona, through 1938.
156-Arizona Zinc and Lead Deposits, Part I.
158-Arizona Zinc and Lead Deposits, Part II.
161-Bibliography of the Geology and Mineral Resources of Arizona, 1939-1952.
162-Pegmatite Deposits of the White Picacho District, Maricopa and Yavapai Counties, Arizona.
163-Minerals and Metals of Increasing Interest - Rare and Radioactive Minerals.
166-Petrology, Condensed and Simplified.
167-Some Rare-earth Mineral Deposits in Mohave County, Arizona.

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RESEARCH AND SERVICE

IN THE

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ARIZONA BUREAU OF MINES
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TUCSON, ARIZONA

MAIN STRUCTURE

UNCLE JAM PORPHORY
(INTRUSIVE MASS OF QUARTZ LATITE PORPHORY.)

LATE CRETACEOUS OR EARLY TERTIARY.)

ARIZ BUREAU OF MINE, GEOLOGICAL SERIES
NO.10, BULLETIN NO.143

GEOLOGY AND ORE DEPOSITS OF THE TOMBSTONE DISTRICT, ARIZONA

BY B. S. BUTLER, E. D. WILSON & C. A. RASOR.

VOL. IX, No. 1 & SUPPLEMENT MAP SECTIONS.

BABCOCK - U.S.G.S., TUCSON.

1. INQUIRE IF AEROMAGNETIC MAP SURVEYS BY U.S.G.S WERE MADE OF THIS AREA.

2. INQUIRE IF AIRBORNE RADIOACTIVITY SURVEYS WERE MADE BY U.S.G.S.

3. ANY MINERAL INVESTIGATIONS, RESOURCE APPRAISALS MAPS OF AREA AVAILABLE THAT ARE NOT LISTED ABOVE.

TOMBSTONE DIST., COCHISE.:

BLAKE, W.P., 7, 8, 34, 40.

BRISMADE, R.B., 4 x S L.P.

BUTLER, B.S. (8), 9, 13, 16

CHURCH, J.A., 1, 2

CLARKE, F.W.; DEVERE, J.; GILLULY, J., 10.

GOODALE, C.W., 1, 2.

HILLEBRAND, W.F., 1

HOLLYDAY, E.F.; LAKES, A., 2

MOSES, A.J., 1, 2, 3, 4

NEEDHAM, A.B.; RANSOME, F.L., 26.

RASOR, C.A. 1, 2, 3, 4

SHAW, S.F., 2.

STAUNTON, W.F., 2

TENNEY, J.B., 11

ABOVE FROM BIBLIOGRAPHY OF GEOLOGY & MINERAL RESOURCES OF ARIZONA 1848-1964

BY RICHARD T. MOORE AND ELDRED D. WILSON

BULLETIN 173 -(1965).

UNIV OF ARIZONA PRESS, TUSCON.

MISC. GEOL.
ARTICLES

they should perhaps be classed with contact-metamorphic deposits.

5. In the foot-hills of Madera county, Cal., there is a belt of contact-metamorphic schists (chiefly mica and chiastolite-schists), containing copper-deposits at several places. Two of these deposits, the Ne Plus Ultra, belonging to the California Copper Co., and the Buchanan, were examined. The ore of the Ne Plus Ultra mine is chalcopyrite in a gangue composed largely of a colorless hornblende, resembling tremolite. There are also at this place many dikes of diorite-porphyry. In the clay-schist country-rock there are numerous crystals of chiastolite, often two inches in length. These chiastolite-schists belong to the Mariposa formation. Granitic rocks occur not far distant toward the east. At the Buchanan mine, the enclosing schists contain garnet. The ore is chalcopyrite, associated with a chlorite (resembling delessite), colorless amphibole, pyrite, pyrrhotite, garnet, quartz, and reddish-brown biotite. Granitic rocks are near by.

Tombstone and Its Mines.

BY WILLIAM P. BLAKE, F.G.S., DIRECTOR, ARIZONA SCHOOL OF MINES, TUCSON, ARIZ.

(New York Meeting, October, 1903.)

In a former paper read at the Washington meeting of the Institute, February, 1881,[1] I presented a general view of the geology and veins of Tombstone as then developed. Considerable additions have been made to our knowledge of the ore-deposits since that date, nearly all the mines having been worked down to the general water-level of the district. This water was a bar to further progress in depth and costly pumps were erected at the Grand Central mine and at the Contention. By the united action of these pumps the water was gradually lowered, not only in these two mines, but in all the important mines of the district. Pending a consolidation of interests, an equitable distribution of the cost of unwatering, both pumping-plants were destroyed by fire, and the mines were closed down and remained practically idle for 20 years, until, in 1902, by the efforts of Hon. E. B. Gage, of Arizona, the desired consolidation of the mining-interests was effected and an organization was formed under which the mines have been re-opened, with the intention of working them to a greater depth.

[1] "The Geology and Veins of Tombstone, Ariz.," *Trans.*, x., 334-341.

A new and large four-compartment shaft has been sunk to the 600-ft. level of the Contention mine, or just above the water, 569 ft. below the collar of the shaft. At this level powerful pumps have been placed, and sinking has been extended to the 700-ft. level, where other pumps have been installed and will throw water to the surface.

The pumps are from the Prescott Steam Pump Company of Milwaukee. They are of the direct-acting type, triple expansion, with steam cylinders in pairs of 39 in., 23 in. and 15 in. in diameter. The diameter of the water-plunger is 13 in.; stroke, 24 in.

Tombstone is now directly connected by rail with Fairbank, in the San Pedro valley, and with the overland trunk-lines.

Some of the more important developments and additions to our knowledge of the ore-deposits may be briefly enumerated.

1. The West Side vein has been extensively worked and has produced a large amount of ore, not only from the lateral deposits in limestone, known as "flats," or "blanket-deposits," but from ore-bodies on the plane of the vein to a depth of about 500 ft., or to the water-level.

2. It is ascertained that the lateral deposits, flats, or blanket-deposits, extending from the plane of the vein, or lode, and generally into the beds of limestone, follow the crests of the anticlinal folds rather than the synclines or other portions of the beds.

3. Several such ore-laden anticlinal "folds," or "saddles," or "rolls," as they are locally known, have been developed and quantities of valuable ore have been taken from them.

4. The blanket-deposits have great extension compared with their width, and follow the crests of the folds in their downward pitch away from the intersecting lodes. Several such deposits have been followed from the West Side vein nearly to the water-level.

5. The blanket-deposits appear to have been reinforced, or

enrich y each suc ve crevice, vein, crossing them the limestone anticlines.

6. The former observation and statement, that the heavi largest ore-bodies are found on the lower or down-hill si intersection of the plicated rocks with the crevices or lod sustained and exemplified.

7. Much light has been thrown upon the question of the gin of the manganiferous ores of the Lucky Cuss, the L Sure, the Knoxville, and other mines, by the discovery mass of manganese sulphide—the mineral species alaband in the midst of the limestone upon one of the lower levels of Lucky Cuss mine, near the contact of the limestone with granodiorite. There is little reason to doubt that inclu masses or kidneys of alabandite in the limestone are the so by decomposition and precipitation, of the manganiferous of the pipes or chimneys so common from the surface do wards. These deposits, by the form and relation to the li tone, indicate their deposition from solutions flowing d wards. The alteration of the sulphide by oxidation, with formation of manganese sulphate solutions, would give th ditions requisite. Such solutions would follow the cr downwards, enlarging them by solution of the walls, a same time depositing crusts and masses of manganese oxi replacement, while calcium sulphate would flow away. H ever, we find considerable quantities of calcite in associ which is indicative of its formation as one product of the change.

This explanation of the origin of the manganese oxi also explains the peculiar, irregular forms in which th found. They occupy irregular crevices without the form of the filling of regular fissures. They are ofte like, as shown in sections of the Lucky Cuss and of the K ville mines.

The formation of manganese oxides from mangan phide, and of oxidized iron-ores from iron sulphide, ar gous.

A Laboratory Study of the Stages in the Refining of Copper.

BY H. O. HOFMAN, C. F. GREEN AND R. B. YERXA, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

(New York Meeting, October, 1903.)

INTRODUCTION.

IN refining copper, the metal is melted down in a reverberatory furnace in a more or less oxidizing atmosphere and then further subjected to an oxidizing smelting in order to eliminate the common impurities, most of which have a stronger affinity for oxygen than has copper. In these operations some of the copper is oxidized to cuprous oxide and dissolved by the metal bath. When the quantity of dissolved cuprous oxide has reached about 6 per cent, the metal is said to have been brought to "set-copper." A button-sample will show a depressed surface and, when broken, a single bubble at the apex of the depression; the fracture will be brick-red and dull. It is essential to carry the oxidation to this point in order to know that the impurities have been oxidized as far as it is possible under the given working-conditions. Nearly all the cuprous oxide of the set-copper is now reduced to the metallic state by poling, when "tough-pitch" copper will be obtained. A button-sample will show a flat surface. Upon breaking, it will be found that the former bubble has disappeared and that the fracture has become rose-colored and shows a silky luster. The quantity of cuprous oxide allowed to remain in the copper will vary with the impurities still present in the metal and with the degree of pitch that it is desired to reach. It is essential for the general physical and the mechanical properties of the resulting copper that such impurities as arsenic, antimony, bismuth,[1] lead shall be present in the oxidized state, as they are

[1] This generally accepted statement by Hampe (*Zeitschrift für Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1874, xxii., 121) is doubted by Roberts-Austen (*Journal of the Society of Chemical Industry*, 1894, xiii., 471) who, in discussing Gowland's paper, "A Japanese Pseudo-Speise (Shiromé)," etc., says, "however small the proportion of bismuth in copper might be, it always remained free, it did not unite with the copper."

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For: TSW

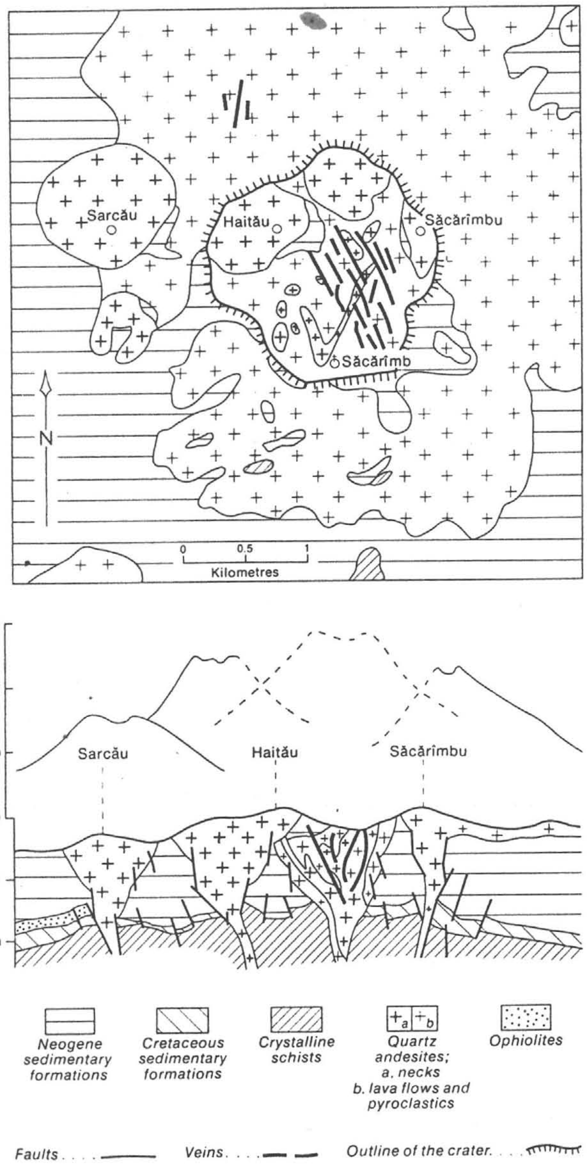


Figure 27. Săcărîmb (Nagyág) volcanic edifice, Apuseni Mountains, Romania (after Cioflica *et al.*, 1973).

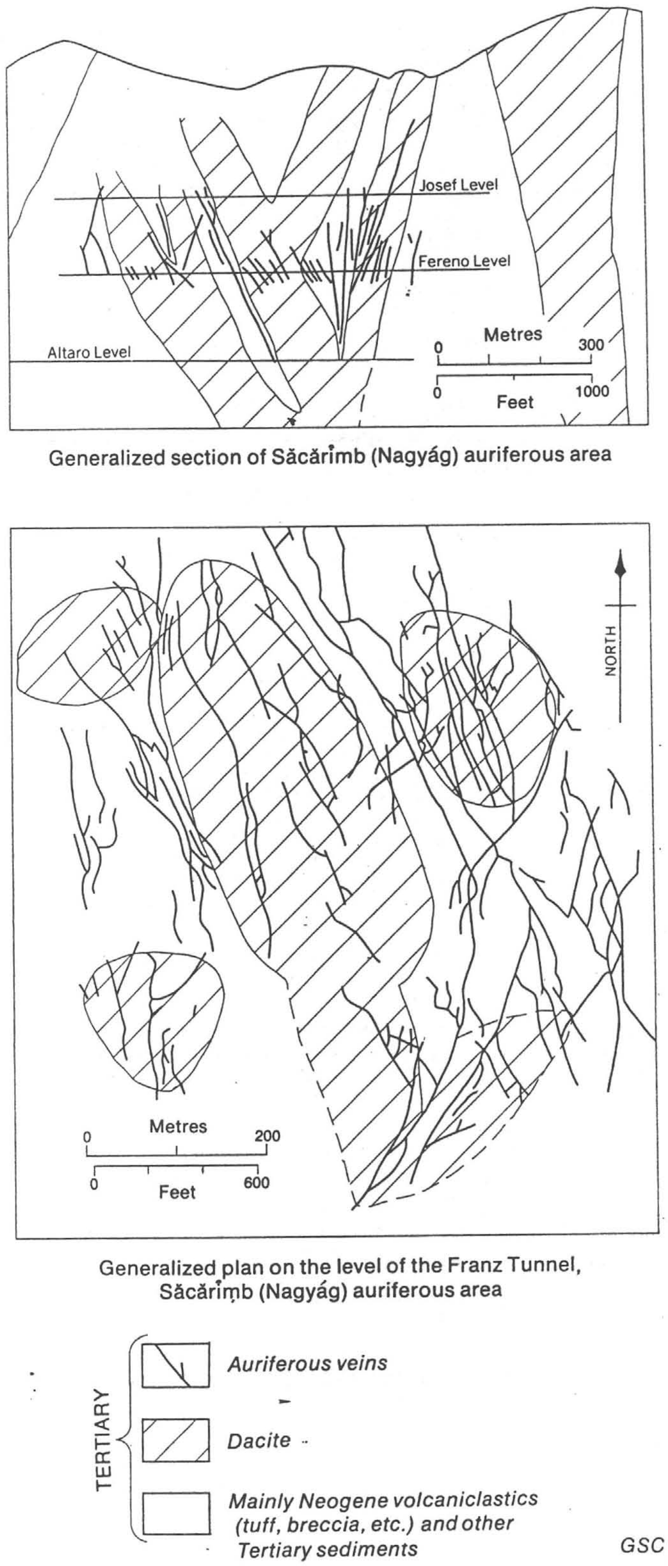


Figure 28. Generalized plan and section of geological features in the vicinity of the Franz Tunnel level, Săcărîmb (Nagyág), Romania (after Von Palfy, 1912).

and altaite. The propylitic alteration of the volcanics is pervasive and regional in extent. Near the veins and stockworks there is a narrow alteration zone marked by the development of pyrite, carbonates, adularia, sericite, locally alunite and clay minerals. The texture of the veins is usually massive and commonly brecciated; banding is relatively rare and vugs are present but not large. 'Glauch' veins barren of gold are a feature of some of the districts. These veins are older than the ore-bearing veins and are interpreted as having been filled by ascending liquid muds containing fragments of shale and igneous rocks. These unusual veins are sometimes found in other Tertiary volcanic areas in many parts of the world.

The mineralization history of the economic deposits is complex. In the Apuseni Mountains, Cioflică *et al.* (1973)

 Tom: This is just about a twin of what I envision for Tombstone recognize three metallogenic phases, oldest to youngest as follows:

1. A gold-silver phase characterized by pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, alabandite, tetrahedrite, pearceite, polybasite, argentite, native gold and marcasite in that paragenetic order. These minerals occur in a quartz, carbonate and rhodocrosite gangue.

2. A gold-silver, base metal sulphide, copper and mercury phase. These deposits are varied and include gold deposits proper, gold deposits with base metal sulphides, porphyry copper mineralization and cinnabar mineralization. The gold deposits proper are characterized by pyrite, marcasite, arsenopyrite, sphalerite, galena, chalcopyrite, alabandite, gold tellurides, tetrahedrite and various other sulphosalts, stibnite, realgar, native arsenic and native gold in that paragenetic order in a gangue essentially composed of quartz, carbonates, rhodochrosite, barite and gypsum.

3. A subordinate base metal sulphide phase characterized in places by tetrahedrite and chalcopyrite, enargite, famatinite, bismuth and germanium minerals, and in places by gold-silver tellurides (sylvanite, hessite) and rarely native gold.

Some of the deposits, especially those with a polymetallic character are markedly vertically zoned as follows from the surface downwards: Au-Ag, Pb-Zn, Cu. In some deposits there is considerable telescoping and several generations of minerals. The geothermometric work by Giuscǎ *et al.* (1968) shows that mineralization proceeded through a large temperature range – 165–269°C for the gold stage and 154–316°C for the polymetallic stage. The grade of the Romanian ores is about 10 ppm Au (0.3 oz/ton). The native gold is relatively rich in silver containing on the average about 25 per cent Ag. The Au/Ag ratio in the deposits as a whole is highly variable especially where silver minerals are present; on the average it is low, about 1:2 to 1:4 judging from the available data. Where the deposits are silver-rich the ratio Au:Ag is in the range of 1:100 to 1:200.

The Tertiary gold deposits of New Zealand occur in the Coromandel Peninsula (Hauraki goldfield) and adjacent regions where andesite and dacite flows of Eocene and Miocene age overlain by Pliocene rhyolites lie on Mesozoic sediments. Several areas have been highly productive, including Waihi, Thames, Coromandel, Kuaotunu, Waitekauri, Komata-Maratoto, Karangahake, Te Aroha and Te Puke. There is an extensive amount of literature on the deposits in these areas, most of which is summarized by Henderson (1930), Emmons (1937) and Williams (1974). Of particular interest are the reports and papers by Park (1897), Fraser (1910), Fraser and Adams (1907), Finlayson (1909), Bell and Fraser (1912), Henderson and Bartrum (1913), Morgan (1924) and Williams (1974).

The deposits at Waihi occurred in a conjugate system of fissures in highly propylitized dacite and andesite. The principal fissure, the Martha, strikes northeast, dips steeply southeast and has been traced for about 1 mi. The subparallel Empire and Royal, and most of the numerous other lodes and fissures, lie to the northeast; they dip steeply northwest and join but, so far as known, do not cross the Martha in depth. Most of the ore-shoots became poorer or terminated altogether at from 600 to 800 ft below sea level.

The orebodies consisted essentially of quartz veins well mineralized with valencianite (orthoclase), calcite, rhodochrosite, pyrite, sphalerite, galena, chalcopyrite, pyrargyrite, acanthite and minor stibnite, native arsenic and molybdenite. The ores were banded and the quartz was colloform (chalcedonic) in some places and lamellar or platy in others. This lamellar or platy quartz is characteristic of some types of Tertiary gold deposits in various parts of the world. Some investigators have suggested that this type of quartz is due to replacement of calcite, but Morgan (1924) thinks this is erroneous. Much of the gold in the Waihi ores was free and there were some tellurides. The grade averaged 0.5 oz Au/ton or more and the Au/Ag ratio averaged about 0.3.

In the Thames area of New Zealand (Fig. 29) the deposits are quartz veins in highly propylitized andesites in a comparatively small downthrow fault block. There was practically no payable ore below a depth of 500 ft from the outcrop of any vein. Fabulous bonanzas characterized the Thames veins, some containing 1 to 6 oz electrum/lb of ore. The principal minerals were quartz, calcite, rhodochrosite, rhodonite, barite, ankerite, pyrite, chalcopyrite, galena, sphalerite, stibnite, molybdenite, cinnabar, argentite, pyrargyrite, hessite, petzite, native arsenic and native gold, the last containing up to 40 per cent silver.

The numerous veins at Coromandel were of the Thames bonanza type. At Te Puke the veins were similar to those at Waihi, but no large bodies of secondarily enriched ore were found as in the latter district. The quartz lodes in the Te Aroha area are mainly in extensive fissures in andesites and dacites. The main fissure or Waiorongomai Buck reef was followed for some 3 mi on strike. It dipped east and consisted of a zone of crushed silicified rock cut by numerous longitudinal and transverse fissures. In places it was 60 ft wide. The mineralization consisted of quartz, calcite, ankerite, rhodochrosite, valencianite (orthoclase), pyrite, chalcopyrite, galena, sphalerite, cinnabar, acanthite, pyrargyrite and native gold, the last ranging in fineness from 645 to 900. The ores of the Karangahake area are similar to those at Te Aroha.

A recent contribution to our knowledge of the Hauraki goldfield by Ramsay and Kobe (1974) is of interest. They studied the silver-gold ores on Great Barrier Island. There, the deposits comprise a number of east-striking, quartz-filled, mineralized fissures that transect andesites and an unconformably overlying siliceous sinter deposit of upper Pliocene to Pleistocene age. The wall-rock alteration exhibits a crude zoning consisting of a general propylitization in the andesites with argillic assemblages and silicification developed close to the veins. The endogene ore minerals comprise pyrite, marcasite, arsenopyrite, chalcopyrite, sphalerite, rare galena and tetrahedrite, acanthite, electrum, silver, chlorargyrite, pyrargyrite, proustite, polybasite-pearceite, argyrodite, aguilarite, naumannite, realgar and stibnite. The principal supergene minerals are limonite, hematite, covellite, native silver, kermesite and cervantite. The electrum is approximately 500 fine, while the Au/Ag ratio of the deposits as a whole is 0.033. The ore is seleniferous, some of the polybasite containing up to 3 per cent Se. The argyrodite is, likewise, selenium-bearing, as is also the galena. The two selenides, aguilarite and naumannite, are relatively rare. The presence of the germanite and argyrodite is of interest, considering that certain thermal waters in

"Millions In It" (5-1-1880)

The Tombstone Epitaph.

VOL. 1--NO. 1. TOMBSTONE, PIMA COUNTY, ARIZONA. SATURDAY, MAY 1, 1880. CLUM, SORIN & CO., PROPRIETORS.

MILLIONS IN IT.

That Is, in the Great Carbonate Camp of Pima County.

Filtered Through the Epitaph for Our Many Readers.

Tough Nut, Good Enough, West Side, Defense, Surveyor.

"Five of a Kind," Held by the T. M. and M. Company.

Surface and Sectional Outlines [illegible]

And Developments Leading to the Recent Strike.

Four Hundred and Twenty-Four Thousand Dollars

Bullion Already Produced and Millions in Sight.

Enough Ore Exposed to Run Both Mills Two Years.

An Additional Battery of Ten Stamps to Be Put In.

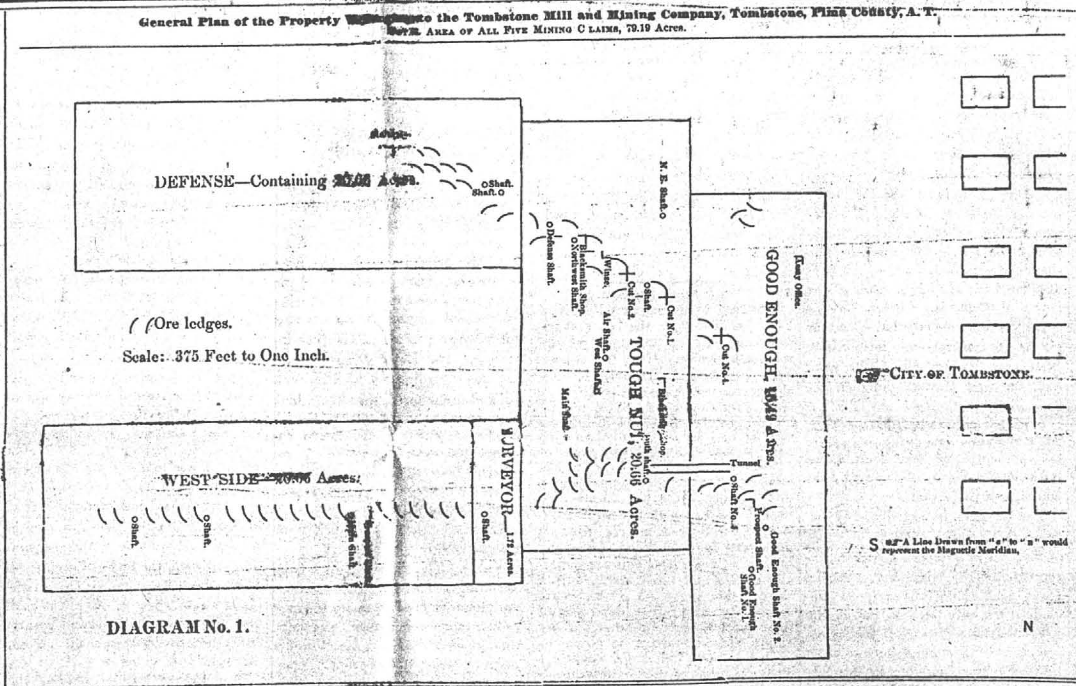
Monthly Dividends Hereafter of $50,000.

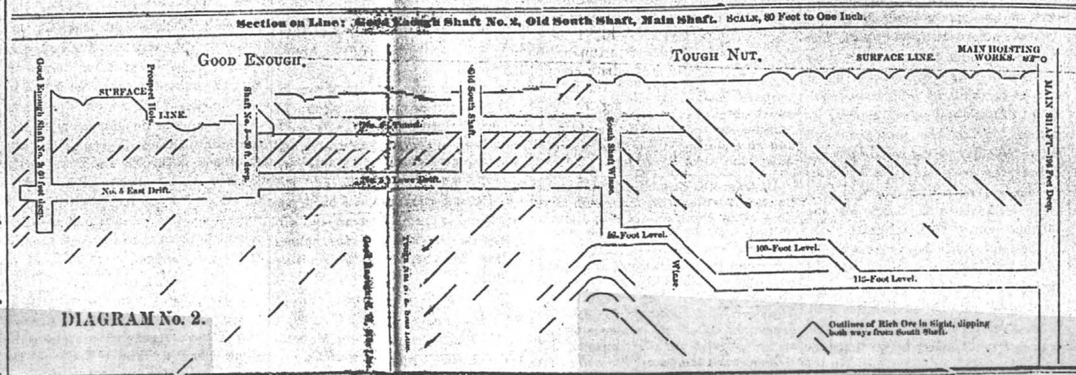
Sale of the Vizina Mine for $35,000.

Outlook of Other Mines in and About the Camp.

Sale of the Hermosa Mine on a Basis of $1,000,000.

Rich Showing in the Turquoise District.





Mining is one of the oldest industries known to mankind. The earliest pages of both sacred and profane history are replete with descriptions of ornaments of gold and silver, though no mention is made of hoisting works, furnaces, arrastras and quartz mills. Whatever may have been the modus operandi of extracting and reducing these precious metals, we know that originally they existed in subterranean deposits as at the present time, and hence the necessary conclusion is that our most ancient ancestors were acquainted with the terms "shaft," "tunnel," "drift" and "cross-cut," and knew how to swing a pick and polish up the head of a tempered drill. That the miner in the time of Moses employed the crudest processes is also a natural conclusion when we note the gradual but important progress made in this "ancient and honorable" industry during the lapse of subsequent ages, under the study and experience of more civilized and intelligent generations, until at the present day it is reduced to a science of wonderful accuracy with corresponding results. A history of the different localities and methods of coal and metal mining in the numerous mining sections of our own and foreign lands is not essential to the purposes of this article, which being strictly local in character has already enough of historical reference by way of introduction.

Arizona, since its earliest exploration, has always been considered a grand treasure house of precious metals. The native tribes of Mexico and their more recent conquerers, the Spaniards, have what seem almost fairy legends concerning the fabulous riches extracted from the great ledges in the north country—which doubtless refer to Southern Arizona and Northern Sonora. During the last thirty years the hardy American pioneer has evinced a restless disposition to penetrate these mountain ranges and by careful exploration demonstrate how much of truth the old Mexican legends might contain. A combination of circumstances—such as a lack of knowledge of the general character of the country, its distance from civilization, the savage tribes by which it was inhabited, etc., tended to deter the most courageous prospector and thus, until recently, the history of Arizona savored much of the character of mythology and romance. Gradually these difficulties were overcome, and the pioneer was always present to make the best possible use of every advantage gained. Thus range after range was prospected, and ledge after ledge discovered, located and opened. The developments encouraged immigration, counties were organized, mining districts formed and the work of exploration actively prosecuted until, at the present time, every section of the Territory, north, south, east and west, is contributing its quota of bright bullion to the commercial market of the world.

The old Mowry reduction works in the Patagonia Mountains and the Ostrich quartz mill in the Oro Blanco District are among the earliest mining enterprises in Pima county. But it was left for Tombstone to bring the boom, the capitalist and the multitude to this section of the Territory; and this brings us flush with the subject proper of this article. We have chosen to present the properties of the Tombstone Mill & Mining Co. in the first issue of the EPITAPH because they include the first mines located in the district, and those in which the original discoverer, Mr. Edward L. Schieffelin, has been, until recently, personally interested. In order to present this property in accurate detail the artist and reporter of the EPITAPH have both been actively engaged for several days, and their labors have resulted in the accompanying diagrams, with notes as follows:

THE DISCOVERY.

Mr. Edward L. Schieffelin, an experienced miner and daring prospector, discovered, August 1, 1877, the Tombstone mining claim, and with it the present mining district. The country being then filled with hostile Indians Mr. S. soon left with ore samples of this first location for the McCrackin Mine, in Mohave County, where he found his brother, A. E. Schieffelin, and his partner, Mr. Richard Gird, who assayed the ore specimens. The results of the assays were very encouraging and the Messrs. Schieffelin and Mr. Gird started for the present district on February 14, 1878. On March 15, 1878, they located and claimed the Lucky Cuss, and on March 22, 1878, the Tough Nut.

Besides the above mentioned mines which soon became household words all over the Territory, they also discovered and monumented the following valuable mining claims, viz: The Contention, Ground Hog, Contact, Owl's Nest, East Side, West Side, Tribute, Goodenough and Defense, all of them being in the Tombstone Mining District and near the present town of Tombstone. While resurveying the West Side it was found that the said claim was about 140 feet too long, and the Surveyor claim, between the south side line of the Tough Nut and the north side line of the West Side, was then established in order to secure both the entire mining ground originally located and the continuity of the claims.

ORGANIZATION.

The locators had great faith in the value of their properties and did all they could with the means at their command to properly open the ledges. The sale of the Contention Mine, in November, 1878, to San Francisco capitalists for $10,000, assisted them greatly in these developments. Finally, through the efforts of Hon. A. P. K. Safford, the Messrs P. and F. Corbin, of New Britian, Conn., were induced to investigate the prospective value of these claims, and having become satisfied as to the vast wealth contained in the property, they at once entered into negotiations with Messrs. Schieffelin and Gird which resulted in the formation of the present Tombstone Mill & Mining Co., with Hon. A. P. K. Safford, President, and D. C. Field, Secretary. To this company belong the following mining claims, viz:

Name.	Size.	Area
West Side	1500 feet by 600 feet	20.66
Defense	1500 feet by 600 feet	20.66
Good Enough	1500 feet by 450 feet	15.48
Surveyor	135 feet by 600 feet	1.73
Tough Nut	1500 feet by 600 feet	20.66

Giving a total of 79.19 acres of very valuable mining ground, a surface representation of which is given in diagram No. 1, on this page.

ORE BODIES.

On the surface of these claims two very distinct ore bearing ledges can be readily traced. The one commences near the south shaft of the West Side and running nearly parallel with the side line of the claim, bisects the Surveyor claim and entering the Tough Nut sinks out of sight. The other crops out in the gulch near the north end line of the Defense and cuts the Tough Nut in a line nearly parallel with the Tough Nut gulch.

Near the south shaft the ore beds are so [illegible] distorted, forming a large saddle. A considerable number of shafts and cuts sunk into these two ledges prove the existence of good bodies of ore, which attain great size and richness in the northwest shaft, Good Enough shaft No. 2 and the south shaft.

Between and off, said ledges are a number of cross courses marked by rich outcroppings on the surface; the northeast shaft on the Tough Nut and the new prospect shaft on the Good Enough have been sunk on them.

FORMATION.

The metaliferous bodies occur in the stratified, or the associated igneous rocks not newer than the Permian. There is abundant evidence of the different agencies—pressure, heat, chemical action, water, etc.—which have contributed to the metamorphism of the rocks met with in Tombstone District. We find in the clay slate a cleavage structure, limestone changed to the condition of marble where in contact with intrusive rock, the effects of water inducing crystalization; deposits of clay from disintegration of feldspathic rocks: limestone converted into gypsum; galena as it passes to a sulphate changed to a carbonate by means of solutions of bicarbonate of lime.

The ore bodies, as far as prospected, lie in porphyry or between porphyry and lime. In connection with the lode irregular masses of rich mineral matter are also found. In the mines belonging to the T. M. & M. Co., silver is found partly as horn silver—kerargyrite, chloride of silver, consisting of 75.3 silver, 24.7 chlorine—and partly contained in a greater or less proportion in lead ores. In the former state it is disseminated in clay slate, calcite, barytes and ochreous varieties of brown iron ore. In the latter case it is chiefly found in the salts of lead, of which the carbonate (cerrusite) predominates. This, again, is usually contained in a silicious matrix, often covered with flakes or specks of horn silver. Malachite and azurite, the carbonates of copper, are also found, they generally overlie or flank the pay ore, while the oxides of iron and manganese usually form the capping of the regular ore deposits. Nearly all the silver bearing ores were found to carry gold, in some instances running as high as $4000 per ton, but averaging from $6 to $12 per ton.

From the books of the T. M. & M. Co., we learn that the grand mean average assay of the battery pulp thus far reduced in their mills has been $139 per ton. The ore works free on an average of 85 per cent. The tailings are saved, mixed with the chemicals used in the working, they will yield, after years of exposure to the air, on a second reduction, about 60 or 70 per cent of the remainder.

The walls consisting of porphyry and lime necessitate drilling and blasting operations. The drilling is done by hand, and dynamite, the giant powder of the Pacific Coast, is generally used as a high explosive. The charges are detonated by the fulminate caps attached to the ordinary powder tape fuse, as furnished by Alfred Nobel's agents. In the removal of chlorides and pure carbonates, which constitute the principal pay ore, the pick and shovel often suffice. Very little timbering has been necessary in the underground work, and no water has been encountered in any shaft or drift.

The hoisting is done by windlasses on all shafts with the exception of the main shaft and the northwest shaft where the company have steam hoisters. Near the shafts are dumping platforms from which the ore is shoveled into wagons for transportation to the company's mills. The ventilation in the underground workings is good in all portions of the mine.

The subjoined table gives an approximate statement of the extent of excavations carried on in the different claims up to date:

Name of Mine.	Total Depth of Shafts.	Total Length Levels and Drifts.	Total Length of Cuts.
Tough Nut	805.0 feet	2,461.0 feet	484 feet
Good Enough	299.7 feet	502.6 feet	60 feet
West Side	113 feet	....	....
Defense	19 feet	....	....
Surveyor	10 feet	....	....

The shafts are about 5x7 feet, the levels and drifts 4x7 feet, and the cuts 4 feet in width.

THE MILLS.

Soon after the organization of the company a ten-stamp mill was ordered from the Fulton Iron Works in San Francisco, which was at once built and shipped to the company's mill site on the San Pedro, where the company own 500 acres of valley land, including the town of Charleston. The company also control the entire water right on the San Pedro River from their mill site to the Sonora line, a distance of about twenty miles. The foundation having been previously graded the mill was soon set up and on June 1, 1879, began crushing the ores from the Tough Nut Mine. Since that time the mill has been running constantly, with the exception of about a month during which time the necessary changes were being made for the substitution of the wet process instead of the dry, which had been formerly used. The waters of the San Pedro, banked by a substantial dam and conducted, partly in an open cut and partly in a strong wooden flume, are utilized for driving the turbine wheel which constitutes the motor of the mill. The work of construction was directed by Supt. Gird, assisted by J. S. Vosburg, who is also interested in the property.

About March 14th, of the present year, a sale was consumated by which the Corbin Brothers, Hamilton Disston, of Philadelphia, and others, purchased the entire interest of the Scheiffelin Brothers in this property, on a basis of $2,000,000 for the whole; and by this transaction the Corbin Mill became a part of the property of the new organization. This mill is also located on the right bank of the San Pedro, near the smaller mill. It was built by the same parties in San Francisco, and has fifteen stamps, which are propelled by steam. In this mill the dry process is used. These mills, resting upon solid rock, are constructed upon the most approved plans for amalgamation, and run like clock work.

COST OF REDUCTION.

The ore is transported in large wagons from the mines over good roads [illegible] the mills. fifteen tons to a [illegible] price of $4.15 per ton. [illegible] present rates the cost of reduction of pay ore per ton is as follow; Mining, $2.50; transportation, $4.15; reduction at the mill, $5; making a total cost of $11.65 for each ton worked. The capacity of the two mills thus far is about fifty tons per day. Superintendent Gird is now absent in San Francisco to arrange for an additional battery of ten stamps, which will materially increase the company's facilities for the reduction of ores. The daily production of bullion at present varies from $3500 to $4000.

THE BULLION PRODUCT.

From the date the first stamp dropped in the Tombstone Company's mill, on June 1, 1879, to January 1, 1880, just 100 bars of bullion had been produced, representing a value of $222,008.34. From January 1 to March 15, 1880, forty-eight bars more were turned out, valued at $94,116.60. From March 15, 1880, to the present date fifty bars, with a value of $107,874.06, have been added to the bullion product of this property, making an aggregate of 198 bars, with a total valuation of $424,000. This is indeed a magnificent showing, considering that until within the last month the company has only had ten stamps running on its ores. The bullion is shipped through Wells, Fargo & Co. to the banking house of Safford, Hudson & Co., in Tucson.

AT THE MINE.

Having been invited by the company to make a personal examination of the underground workings the EPITAPH reporter presented himself at the company's office where he was taken in charge by Foreman Baron and afforded every facility for a thorough examination of the various developments, making the following notes on the trip.

Mr. Baron escorted us to the building over the main shaft, where the largest hoisting works are situated, having a capacity for hoisting from a depth of 800 to 1000 feet. Entering the bucket we were lowered down a well timbered shaft to the 113-foot level, the entire depth of the shaft being 196 feet. This shaft was sunk for the purpose of running drifts to cut the ore body which had been previously opened by the older cuts and shafts, and which runs south of the main shaft through the West Side cliam. This ore body was reached in the 113-foot level at a distance of 170 feet from the main shaft, showing broad strata of the same character of high grade carbonates found in the old south shaft and Good Enough shaft No. 2. From the 113-foot level an uprise connects with the 100-foot level which also exposes the great ore bodies of this ledge. Connection has also been made between the 100-foot level and the drifts from the west shaft. Considerable stoping has been done in these drifts leaving large subterranean chambers which, on account of the solid formation of the walls, require but little timbering to hold in place. On the 113-foot level, at a distance of 350 feet from the main shaft, an incline is reached which rises to the 88-foot level, which level is connected with the No. 5 lower drift and No. 5 tunnel by means of the south shaft winze, as shown in accompanying sectional diagram, No. 2.

The No. 5 tunnel and lower drift were run to cut the immense body of ore discovered in the old south shaft, from which body a considerable portion of the ore already worked in the mills has been taken. This is an extensive but irregular deposit of very rich ore which rises to within a few feet of the surface, having a horizontal measurement of about 70x35 feet the depth and value of which it would be folly to attempt to calculate. Another ore body of considerable size has been struck in the end of the No.

[Continued on Fourth Page.]

BLAKE (1882)

work is expected of American chemists. The presence of arsenic is so rare in American irons that it is hardly necessary to mention the fact that where it is present the precipitation with molybdate must be made in a cold solution. My attention was lately drawn to this element by finding 0.05 per cent. in an iron sent out by chemist L. for the purpose of comparing results by different methods. My result on this iron was reduced from 0.180 per cent. to 0.152 per cent. of phosphorus by taking the above-mentioned precaution.

To sum up, I find of three chemists working the acetic and citric acid methods in list A, two are wrong. Of four who worked the direct molybdate method three are wrong, and the fourth has a variation of 0.010 per cent. in the method as regularly worked by him. Of three working the modification of the molybdate-magnesia method, in which there is a large quantity of chlorides present with the nitric solution when phosphorus is precipitated, all are wrong, and of ten working the method so that there is only nitric acid and ammonium nitrate present with the iron solution, nine are within the limits of error.

THE GEOLOGY AND VEINS OF TOMBSTONE, ARIZONA.

BY WILLIAM P. BLAKE, F.G.S., NEW HAVEN, CONN.

THE mining district and the town of Tombstone are situated in Cochise County, Arizona Territory, at the northwest end of the Mule Pass range of mountains, in longitude 110°, and latitude about 31° 40′ N., upon the right bank of the San Pedro River, from which the town is distant 9 miles east. It is also 24 miles south of Benson station on the Southern Pacific Railroad of Arizona, and about 40 miles north of the Mexican line. Its altitude above the sea is 4600 feet. The Dragoon Mountains rise across a valley to the northeast, and the Huachuca Range similarly upon the southwest. The country is open, without timber, and the surface, where the mines are opened, is in general gently rolling, and accessible to wagons by natural roads.

The first locations were made in the year 1878 by the Scheffelin brothers and Richard Gird, the latter being well known among the pioneers of Arizona as a surveyor and miner, who contributed largely to our knowledge of the geography of the Territory in early days,

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when the dreaded Apache dominated the region. There are now, probably, over one thousand locations or claims in the district, and upwards of 2500 inhabitants.

The output of the precious metals, gold and silver, up to the first of January, 1882, aggregates $7,359,200, and over $3,000,000 have been disbursed in dividends. This product is distributed among the following-named mines and mills:

Production of Tombstone Mines and Mills.

Tombstone Mill and Mining Company,	$2,704,936 33
Contention Consolidated,	2,703,144 39
Grand Central,	1,050,875 30
Head Centre,	191,520 52
Vizina,	526,716 98
Ingersoll,	15,000 00
Sunset,	15,000 00
Corbin Mill,	40,000 00
Boston Mill,	112,007 83

Dividends.

Tombstone Mill and Mining Company,	$1,100,000
Contention Consolidated,	1,375,000
Grand Central,	600,000
Vizina,	80,000

This will suffice to show the importance of the locality for mining, and to indicate at the same time the principal claims.

GEOLOGY OF THE DISTRICT.

In going from the railway at Benson to the mines the traveller rises from the post-pliocene deposits along the San Pedro to a granitic plateau. The rock is gray and highly crystalline, and is apparently eruptive. It weathers in places into gigantic rounded blocks and masses, lying one upon another as if piled there by some Titanic force, rather than by the gentle and gradual effects of irresistible decay. This rock extends to within a mile or two of Tombstone, where stratified formations occur overlying the granite.

These stratified beds consist of quartzites, limestones, and shales, with frequent repetitions in an ascending series several thousand feet thick, but all conformable and dipping generally at a low angle from 20° to 45° to the eastward. The fossils which have been found in the middle and upper beds, consisting chiefly of *Productus* and cyathophylloid corals, show them to be *Paleozoic*, and probably

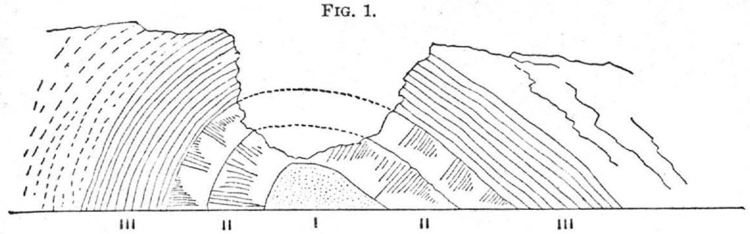
Lower Carboniferous. The lower strata are probably older. A small shell, like *Lingula,* occurs in the shales of the Contention mine.

In addition to the stratified formations we find intrusive porphyritic dikes cutting through the strata indiscriminately, nearly at right angles, and trending approximately north and south, or a little east of north. This is the direction of the general rift or breaking of the country and of the mineral veins.

In the central portion of the district, covering the claims known as the Toughnut, Goodenough, Way-Up, Vizina, and others, erosion has exposed the outcropping edges of many strata of limestone, shales and "quartzites." Both the shale and so-called quartzite beds are of deep-sea origin, being very fine and compact in texture, with scarcely any signs of granular structure. The latter, particularly, is flint-like and very hard, and is more exactly described as a novaculite or honestone. In places it passes insensibly into limestone, apparently forming beds of silicious limestone. It is, no doubt, largely organic in its origin, and is a very fine sediment, totally different from the typical quartzites, with granular structure, found in the higher parts of the series of strata. It evidently, in forming, accumulated slowly, beyond the influence of currents, at the sea-bottom. An abundance of iron pyrites in fine crystalline grains, disseminated through the layers of this rock, gives evidence of its organic origin in part, at least. This rock has special importance from the fact that the miners in the Toughnut and Goodenough claims find it *below* the chief ore-bearing limestone. It is regularly and evenly stratified for a thickness of about 140 feet, and rests upon a thickly-bedded dolomitic limestone below. The beds above it consist of dark, black or blue limestones, and of thick beds of dark argillaceous shale, alternating with black silicious shales for nearly half a mile to the eastward. The black limestones above the novaculite are the chief repositories of the bedded masses of rich silver ore, as will be presently shown.

The whole series of beds in this central part of the district is thrown into folds, being regularly plicated in a series of wave-like flexures, the steepest and sharpest folds being on the northwest of the Toughnut and Goodenough claims facing the granitic region in that direction. These folds may be traced, but with difficulty, upon the surface, but are best seen in the crosscuts of the mines and along the drifts. In the open cut upon the Toughnut there is a good exposure of some of the beds at the crest of an anticlinal fold presenting an appearance in section, along a northeast and southwest cut, nearly as shown in the annexed drawing:

FIG. 1.



Anticlinal fold. Toughnut.

I. Novaculite—under the limestone.
II. Limestone—bending over the novaculite.
III. Shales—bending over the limestone.

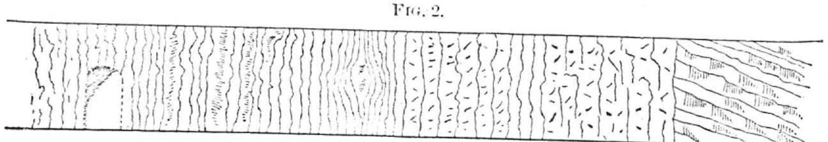
This little section is along the upper level known as the "adit." It is directly below the place on the surface where ore was found cropping ou[illegible]d with soil and vein-stuff. At another place, upon the western end of the Goodenough, we find a series of plications, up and down, at about the angles shown, and with rich ore lying in the folds. These folds are not large, covering only a few hundred feet in extent, but are beautifully regular and well defined. As we pass up the hill, rising higher in the series of strata to the eastward, the dip becomes more regular, and coarse-grained quartzites, in thicker beds, take the place of the finer-grained deposits.

All of the formations named have not only been uplifted as described, but have been much broken and faulted either at the time of uplift or at long periods later. This is shown by the number of fissures and lines of fault, as well as by the outcrop of dikes of porphyry, and the dissimilarity of the stratified beds on either side of them, and the disjointed outcrops of the limestone beds.

THE CONTENTION MINE.

The chief fissure and ore-bearing vein of the district traverses the Grand Central and the Contention claims. These claims were located in a north and south direction upon the somewhat obscure croppings of a dike of dioritic porphyry carrying ore, in, through, and alongside of it. This location was made by Messrs. White and Parsons. The croppings were not remarkably well defined, consisting of the porphyry and a confused mixture of porphyry, chert, and quartz, with masses of porous quartzite alongside; none of these rocks rising high above the soil. There was, however, a considerable discoloration of the soil by iron-rust along the line, and a little digging revealed good ore near the surface. The harder parts of the dike were the most prominent, and its direction governed the direction of location of the claim. This dike varies in width from a few feet to 50 feet or 70 feet, and dips to the westward at an angle of from 55° to 65°. It cuts indiscriminately through shales, quartzites, and limestones, and is evidently of igneous origin. The contact, however, with the abutting edges of the disrupted beds is not always marked by any great change in their appearance or composition, though in places there is obscure metamorphism, impregnations of silica, and some modifications of structure. The dike itself has a distinct vertical lamination or structure through most of its substance, and is more or less penetrated by veinlets of quartz. In some portions it is highly crystalline and nearly barren, and in others consists chiefly of a feldspathic base, in which the feldspar crystals are obscure. It passes into a felsite, which, in the decomposed portions of the dike, and when slaty in structure, might be mistaken for the partly decayed shales or quartzites. Large portions of the dike are so penetrated by quartz as to consist largely of it, and might be called quartz, although close examination will show the presence of feldspar.

Fig. 2.



The accompanying cross section (Fig. 2) of the chief part of the dike taken on the first level of the Head Centre mine, upon the Contention lode, will convey a better idea than can be given in words. It shows the vertical structure, and the general distribution of quartz in vertical seams or layers, and in one place a vug, or cavity, in which there are distinct quartz crystals. In general, however, combs of quartz crystals are wanting; the quartz being in an amorphous, subvitreous state, or in the form of chert. The lamellar arrangement of this quartz near the central part of the section is shown by the little cut of full size (Fig. 3) of a fragment ground down to a plane surface. The lines represent the layers of quartz; the intermediate spaces are filled with feldspar. This lamination is typical of the vertical structure of the dike. Another fragment, with less quartz, taken at a distance of about two feet from the first,

Fig. 3.

consists chiefly of a felsite base with obscure crystals of feldspar sparingly distributed. Examination shows it to be penetrated irregularly by veinlets of quartz, as shown by the accompanying sketches from ground and polished surfaces. (Figs. 4 and 5.)

Fig. 4.

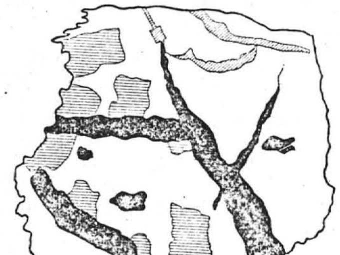
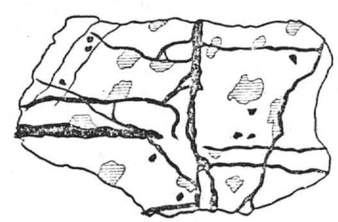


Fig. 5.



There is also a considerable amount of mineralization of the dike by iron pyrites disseminated irregularly in its substance in cubical crystals, most of which have dissolved out and left the cavities only to indicate their former presence, making in some places a spongy mass of porphyry or of quartz. Although the mine has been worked to a depth of 600 feet, and there are some 12 to 15 miles of drifts, levels, and winzes in the Contention and adjoining mines, the undecomposed ores below the water-line have not yet been reached and mined, and all the ores above are in the decomposed and oxidized condition common to surface ores. A large part of the ore is highly charged with red oxide of iron, to such an extent that the clothing of the miners becomes saturated with the rouge-like powder, and the tailings at the mills are blood-red.

There has been an extensive decomposition of the porphyry, especially along the upper 300 feet of the dike, resulting in the formation of quantities of white clay, kaolin, sometimes perfectly snow-white and pure, but generally more or less mixed with red oxide of iron. This kaolinization extends in places to the adjoining shales, and there are some white, claylike, interstratified beds which may, on further examination, be found to be altered felsitic offshoots from the dike. It is not yet possible to say what the exact nature of the ore below the water-level will be found to be. The only metallic contents so far found, with the exception of the pyrites and some galenite and lead carbonate, are gold and silver in a comparatively free state; part of the gold, if not all, being free, and the silver occurring chiefly as chloride, or horn-silver (with probably some iodide), in crusts and films, also occurring in minute crystals upon cleavage surfaces. The average value of silver and gold in the ores worked last year was about $70 per ton. The gold has of late increased from 20 to 25 per cent. of the value of the product, the rest being silver.

GOLD IN PORPHYRY.

One very interesting fact is the occurrence of free metallic gold, together with chloride of silver, in the midst of the porphyritic rocks, at a distance of many feet from the portions of the porphyry carrying quartz in veins, and disseminated. This gold is found chiefly in a portion of the rock apparently dioritic, containing finely-disseminated hornblende. In decomposing, this porphyry becomes steatitic, and in places appears to be changing to serpentine. The gold is found in thin sub-crystalline flakes and scales, chiefly in and along thin seams and cracks in the mass of the rock, as if it had been infiltrated and deposited from solution. This is probably the fact, and the magnesian nature of the rock has no doubt exerted an important influence in its deposition. Free gold is also found in quartz in the usual manner of association, but even in such specimens the crystalline feldspar of the dike is found.

METALLIZATION OF THE DIKE.

The time and manner of metallization of the dike may be considered as open questions, for a solution of which we must wait until the mining extends below the permanent water-level of the formation. It seems most probable that the rock, at the time of its intrusion, was pyritous, and the strata adjoining it no doubt were. It is not impossible that there may have been a concentration of the precious metals in the dike from the surrounding beds, the result of the decay and change of the pyrites diffused in the strata. On the other hand, we may suppose that the dike has been the source of the silver and gold we find in and about it.

In either case the vertical laminated or stratiform structure parallel with the walls has been an important factor in the distribution of the metals, and in the changes and modifications of the original condition of the dike. We may readily conceive of such vertical planes of structure affording planes or lines of least resistance to vertical movements, while the abutting ends of the strata, in contact with the walls of the dike, would offer great resistance by friction. The condition of the dike along a great part of its course seems to sustain and verify this hypothesis. There has evidently been considerable movement of parts of the dike upon itself, resulting in the

formation of heavy clay seams and brecciated layers of porphyry and quartz, sometimes occupying a medial position along the dike, sometimes at one side or the other, and again along the line of contact with the country rocks. Such seams and brecciated ground are sometimes wanting, and the structure and condition of the dike remain unchanged.

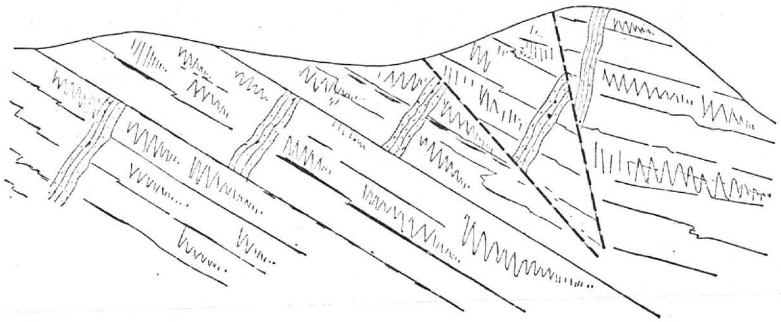
The whole of the dike with the adjoining strata have been subjected to extensive movements and displacements, shown not only by breaks of continuity, but by the brecciated cross-courses and seams traversing both the igneous and stratified formations. One of these faults resulting in a throw of the northern portion of the Contention lode 150 feet to the west, and partly outside of the west side-line of the claim, has recently led to expensive litigation. The faulting seam or break has been drifted upon between the two ends of the disjointed dike. It consists of a heavy breccia of fragments of the adjoining strata, together with a strong clay wall, marking the plane of greatest movement and slip. Its direction is southwest and northeast.

In addition to the lateral movement there have been extensive vertical displacements, and it is probable that the lateral shifting may be referred to them. It would be premature to attempt an exact description of the numerous faults and mechanical changes to which the dike has been subjected. They require further study and surveys. Mr. Isaac E. James, so long and well known upon the Comstock lode as an accomplished mine engineer, is now in charge, and has the subject under investigation. We owe the first determination of the nature and position of many of the vertical faults and throws to his careful observation and surveys. Without now entering into precise descriptions of particular displacements, it will suffice to give a sketch indicative of what has occurred, producing such a confused recurrence of ore upon certain levels of the mine, as to lead at one time to the supposition that there were several dikes of porphyry and ore over a breadth of five or six hundred feet.

The movement appears to have been from the west eastward and downwards, the top of the dike being carried off in successive blocks by the sliding of masses of the stratified formations partly upon the planes of deposition of the beds (these dipping eastward and affording surfaces of easy movement), and partly upon steeper planes of fracture generally dipping eastward, as shown in the outline sketch section, which may be taken as typical.

This disruption of the dike, with its attendant fracturing and brecciation of the country rock, accompanied by the movement of the dike upon itself, and the formation of heavy clay seams, has provided favorable places for the accumulation of ore. It is generally found in the softer and most broken portions of the dike, coincident, no doubt, with the regions of greatest original metallization and subsequent movement, attended by clay seams. Such clay seams, with the accompanying ore, have by some been considered as marking

FIG. 6.



the limits of a second or subsequently-formed vein, following the dike and independent of it. This theory, formed under the inspiration of the necessity of narrowing down the vein and throwing it as far west as possible, in order to secure a greater length of it upon the Head Centre ground, would be more defensible, if in the stopes any vein structure referable to a later deposition could be found. Instead of the fragments of broken porphyry, shale, and quartz being cemented together by quartz, they are loosely aggregated, and show clearly that the formation is due to mechanical force and attrition. The clay seams are also not certain boundaries of the ore; it occurs on both sides of clay seams. The clay cannot, therefore, be taken as separating ore from waste. The seams, moreover, are not continuous, but give out, and in some parts of the dike are absent.

The only place upon the lode where water has been reached is upon the Sulphuret claim. At this point the lode intersects strata of limestone, and there is a bedded layer of ore following the stratification and connected with the dike. This ore is chiefly galena and iron pyrites. Very little has yet been taken out. So also in the Head Centre ground, at a higher level, where the dike intersects limestone, a bedded or interstratified layer of ore occurs. But the best examples of bedded deposits in the district are in the Toughnut and Goodenough claims before referred to.

BEDDED ORE DEPOSITS.

These also are associated with dikes and vertical fissures nearly parallel with the Contention lode. One of the longest and best defined is the West-Side lode, which may be traced for about two miles, until it passes into the underlying granite. Its northern prolongation appears to cut across the Toughnut claim, and to connect with the vertical fissure and quartz croppings at the Discovery shaft on the Goodenough.

A second line of fissure cuts across the anticlinal line of the formations at the open cut on the Toughnut, and crosses the whole breadth of the Goodenough into the Way-Up claim beyond. This has been followed on ore from the open cut to the Way-Up, and is connected with the chief lateral bedded deposits. A lode has also been followed in the same general direction from the claim called the "Defence," across the Toughnut into the Goodenough. This lode is marked by very heavy croppings of quartz and flinty boulders lying above the limestone on the surface.

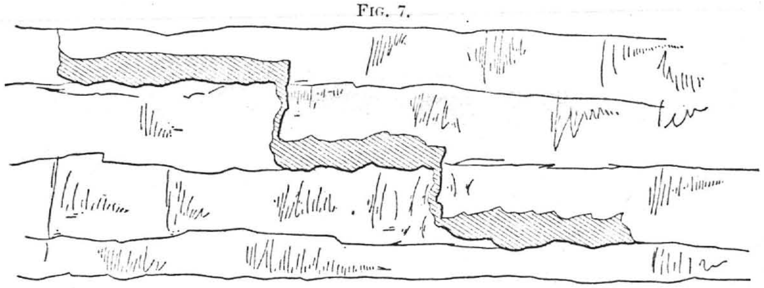
In the fissure extending into the Way-Up claim the ore was found in layers and bunches following the plane of the vein, extending upwards and downwards along its course in nearly vertical shoots or ore-bodies, but breaking off into the adjoining strata in flat bed-like layers, particularly where the vein intersects the lower limestone resting on the novaculite beds. These bedded offshoots from the vein are often of considerable lateral extent, following the planes of stratification on either side. We cannot yet state with confidence what the exact origin of these bedded deposits is. They may be due to the decomposition of nodular masses, but they are generally deposited in the limestone as if by replacement. They may be regarded as filling irregular cavernous spaces eroded from the strata by metalliferous solutions, and without any regular boundaries. These bedded masses do not have a symmetrical arrangement of the ore, except such as may be referred to stratification or deposition by gravity.

It is to be observed that these bedded masses of ore occupy the limestones rather than the silicious or argillaceous strata, as we might expect from the greater solubility of the limestone. Inasmuch as these limestone strata are folded and turned up in different directions, the intersection of the limestone with the vertical plane of the vein is an irregular line. At such intersections the walls of the fissure are corroded away and are obliterated, or are further apart than where the fissure cuts the silicious beds, the shales, or the quartzites.

In this respect the formations are similar to many abroad. Moissenet* represents bodies or shoots of ore corresponding in their pitch to the intersection of strata with the plane of a vein. Wallace describes a series of strata in the North of England consisting of limestones and shales traversed by lodes productive in the limestone, but poor when passing through shales. Other examples might be cited.

In extent, the bedded masses of the Goodenough and Toughnut claims have been much greater than the ore-bodies of the vertical fissures, and it may be said that the greater part of the production has been from the beds or flats. They extend irregularly between the two fissures a distance of about 400 feet, measured diagonally along the dip. It is noteworthy that they follow the stratification, and then suddenly break across it vertically, following a crack or break of the bedding, and then expand again horizontally for some distance to another, dropping down by a series of steps from one layer to another in and between the limestones.

FIG. 7.



The ores found in these bedded deposits in the limestones are much more plumbiferous than the ore of the feldspathic dikes. Galenite, blende, and iron pyrites are abundant in masses, which, within the reach of oxidizing agencies, are largely converted into oxides and carbonates.

Bedded ores of this nature are also found in the limestones of the Blue Monday claim contiguous to the vertical fissure in the westward prolongation of the West-Side lode, or vertical ore-bearing fissure. This contiguity of the bedded deposits of the camp to the vertical fissures and dikes, and the occurrence of bedded ores where the dikes intersect limestone strata, lead me to the opinion that the metallization of the district is due to the igneous intrusions, and that these intrusions, with the accompanying impregnations and ramifying veinlets of quartz, are the true lodes, or "leads," that may be followed with confidence in the search for ores.

* Annales des Mines (6) 9, p. 10.

THE GOLD FIELDS OF THE SOUTHERN PORTION OF THE ISLAND OF SAN DOMINGO.

BY RICHARD P. ROTHWELL, NEW YORK.

IN the year 1881, I visited San Domingo, in the interest of French capitalists, to examine and report upon certain "concessions" of gold-bearing gravel and quartz veins, on the Isabella and Jaina rivers and their tributaries.

This district is periodically reported to be extraordinarily rich, and there is cast around it the glamour of the mysterious shipments of gold, credited, in romance and in more or less romantic history, to Columbus and the Spaniards of the fifteenth and sixteenth centuries. Since considerable sums of money and several valuable lives have been lost in the unsuccessful search for its profitable mines, it seems desirable to place on record some of the information collected concerning the value of these famous gold fields, with the hope of facilitating the work of those who may hereafter be called on to investigate these claims, and of preventing the unnecessary waste of capital.

It is needless to add that the capitalists for whom my investigations were made abandoned the enterprise they had in view, although no doubt similar schemes will be brought forward many times in the future, as they have been in the past, under the fervent advocacy of too sanguine enthusiasts.

Since the time of the Spanish occupation of the Island of San Domingo, in 1497, when Columbus found the natives wearing ornaments of gold, more or less of the precious metal has been obtained annually by washing the gold-bearing sands of several of its streams. It is said that during the Spanish domination, when the native Indians were held in the most abject servitude, a certain amount of gold was *required* of each one as the result of his labor. Under this

TRANSACTIONS AIME (1883)

The consumption of wood, per ton of ore, was 0.15 cord, and of quicksilver 0.96 pound.

The Mills at Charleston.

Most of the mills working the ores of the Tombstone district are distributed along the line of the San Pedro River, at an average distance of ten miles from the mines at Tombstone.

The works at Charleston, of which I am manager, are the property of the Tombstone Mill and Mining Company, and are under the general supervision of Professor John A. Church.

These mills were originally intended for dry crushing, and were provided with rotary dryers, automatic roasters, and all the necessary paraphernalia for a chloridizing roasting, as it was expected that the ore would become base as depth was obtained in the mines. But, contrary to expectation, the deposits retained their free milling qualities as they went down, and the furnaces were never brought into requisition. Upon ascertaining the true character of the ore under treatment it was decided to change the batteries to "wet crushers," in order to increase their capacity, which alterations injured the symmetry of the plant, and left it working at some disadvantage over what might have been had such a change been foreseen in the original designs.

The smaller of these mills (the Pioneer mill of the district), was originally built by the company as an experiment, and constructed with an eye to economy; a wise precaution, as many have learned to their cost who have anticipated developments in their mines by the construction of expensive reduction works. This mill was originally fitted with ten stamps, four pans, and two settlers, and run by a Leffel turbine, water being brought in a ditch from a dam about one mile up the river. Later, in order to increase the capacity, five stamps, two pans, and a settler were added. To run this additional plant up to the necessary speed required more power than the turbine could furnish, so an engine was purchased as an auxiliary. The second and larger mill was subsequently acquired by the company. As both mills run on ore from the same mines and the processes are identical, a sketch of one mill will suffice for both.

It is to be regretted that owing to the separation of the mills, consequent doubling of the pay-roll, and increased expenses from every source, the cost of milling given below will be scarcely a guide to what could be done with a properly arranged plant. I do not hesitate to say that with altered conditions a reduction of 20 per cent. per

Transactions AIME v. 11. pp101-106. 1883 ton in the cost of ore milled could be effected, the quality of the work remaining the same.

In the following hasty sketch reference is had to the larger mill alone. The power is furnished by a horizontal engine with Corliss bed and Meyers patent cut-off, making 70 strokes per minute. The cylinder is 16″ x 36″. This engine runs with remarkable smoothness, and is not shut down more than once in sixty days, and then only to afford an opportunity for cleaning out the boilers, in which, owing to the water used, a scale rapidly collects. These latter are tubular, 54″ x 16″, and carry steam from 90 to 100 pounds pressure. Farciot's patent pump and heater feeds them, pumping the water in at boiling-point. They consume on an average seven cords of mixed wood per day, costing $9 per cord; black oak, white oak, willow, and pine being used indiscriminately. All the water for the mill is pumped a vertical height of 100 feet by a No. 5 Knowles steam pump, placed 200 yards from the mill, which readily supplies more than is consumed. Steam is carried to this pump from the mill boilers. The ore is brought down from the mines, a distance of ten miles, in wagons. These wagons are connected in pairs, weighing about 5 tons; they carry 14 tons of ore between them, and are drawn by sixteen mules. This hauling is done by contractors at $3 per ton. The bottoms of these wagons consist of a series of pieces of plank, 6″ x 2″, laid crosswise, their ends resting on the framework of the wagon-bed, so that, when removed one at a time, they allow the ore to drop out, and permit a rapid and easy unloading. It requires on an average twenty minutes to unload a pair of wagons constructed on this plan, and, as they are filled at the mines from self-discharging shoots, the driver has little labor in loading and unloading.

The ore is wheeled in barrows from the dump to the crusher through which it all, coarse and fine, passes, no screens being provided. One of Hendy's breakers is used. The bottoms of the shoots leading from the breaker to the bins are, for a distance of 5 feet, made of $\frac{1}{4}$″ steel bars set $\frac{3}{8}$″ apart, allowing all the finer materials to fall through on to a shaking screen hung below. This shaker is provided with the same screens that are used in the batteries, and separates that portion of the ore already sufficiently fine not to need crushing, which is sent direct to the pans. This relieves the batteries materially, and decreases the amount of "slimes." By this simple contrivance the capacity of the mill was increased 5 per cent., or more, the amount depending on the fineness of the ore, and also on its percentage of moisture.

The batteries are fed from the bins by the Hendy "Challenge" self-feeders, which here, as elsewhere in my experience, give entire satisfaction. The stamps are 20 in number, drop 100 times a minute, fall $6\frac{1}{2}''$, and when freshly shod weigh about 750 pounds; the weight being divided as follows:

Stem, ...	340 pounds.
Boss, ...	200 "
Tappet, ...	90 "
Shoe, ...	120 "

The die weighs about 85 pounds. Some of the stamps carry extra tappets, bringing their weight up to 800 pounds and over. The shoes have an average life of one month, and when worn out weigh about 35 pounds. A novel feature of these batteries is the arrangement of the guides; instead of being grooved to receive the stem, square recesses are cut into which wooden keys are fitted, so that the grain of the wood is parallel to the motion of the stem, instead of across it, as is usually the case. With such an arrangement the guide-boards themselves are subject to no wear, the keys being easily taken out and replaced. This plan might be advantageously adopted where light stems are in use which are liable to spring, and in such a condition saw out guide-boards very rapidly. But when stems of $3\frac{1}{4}''$–$3\frac{1}{2}''$ are used they present no advantages over the old plan. The mortars have double discharge, but the rear discharge has been blocked up with wood faced with iron plates, as close to the stamps as practicable. The average product of these batteries, during the first six months of the year, including stoppages, has been 2.9 tons of medium hard rock to the head of stamps, per day of 24 hours, crushed through a 30-mesh screen. Various screens have been tried, but the best results have been obtained from Russian iron screens, vertical slotted, with a burr on the inside.

From the batteries the pulp goes into settling tanks. The pans, eight in number, are flat-bottomed, 5 feet in diameter, 3 feet high, and have wooden sides of Oregon pine curbs, $2\frac{1}{2}$ inches thick. The die is a solid cast-iron ring $1\frac{1}{2}$ inches thick, weighing 750 pounds, and occupying most of the space between the cone and sides. It is fastened in with Portland cement. The muller, weighing 570 pounds, carries eight shoes weighing collectively 816 pounds. Each pan is provided with three wings shaped like a reversed ploughshare. The settlers are 9 feet in diameter with iron mullers shod with wooden shoes 6 inches high. On the average a ton and a half, dry weight, of sand and slime are put in a pan for a charge, and the time required for amalgamation varies from three to five hours after charging the quicksilver. Repeated experiments have shown that little is gained by running the pans over four hours; the same ore, treated side by side under the same conditions in pans, running respectively on four and six hour charges, gave a gain of one per cent. in favor of the six hour charge, but this slight advantage did not compensate on low grade ores for the limited capacity of the pans. Tests made on pulp while undergoing amalgamation showed that one hour after charging quicksilver, 74.66 per cent. of the silver was already taken up, and that in the succeeding hours 76.26 per cent., 77.74 per cent. respectively, until the end of the fourth hour, when 81.04 per cent. was found to have been extracted.

After that period nothing material was gained by prolonging the operation. For a long time, owing to the excellent quality of the ore, no auxiliaries, other than steam and the iron of the pans themselves, were needed by the quicksilver to effect amalgamation. Identical results were obtained with or without the use of chemicals. Little by little a change crept in, the milling percentage sank, the bullion became less fine, and sulphurets of the base metals made their appearance in the ore. Tests made with a view of determining the aid to be derived from the use of bluestone and salt, showed that in an ore containing only 7 per cent. of its silver in the form of chloride, 87 per cent. of the silver present could be brought into combination with that element by the aid of these two "chemicals." The remaining 13 per cent. was apparently shut up in the base sulphurets and carbonates, and could not be chlorinated in the pans. The result of a series of experiments with these and other reagents led to the adoption of 150 per cent. of bluestone and 500 per cent. of salt, the amount of silver in the ore being taken as 100 per cent., and by this means the milling percentage was brought back to its former standing. Still the bullion resulting left much to be desired. The question then resolved itself into this, how to make fine bullion from very base ores, and at the same time to keep up a satisfactory milling percentage.

Three methods suggested themselves, namely, either to prevent the amalgamation of the base metals in the pans,* or if that proved impracticable, to eliminate them from the amalgam before retorting, or during the melting. Although several metals were taken up by the quicksilver, in varying quantities, and so found their way into the

* I am indebted to Mr. J. M. Adams, of San Francisco, for valuable suggestions in regard to the handling of ores containing lead in pan amalgamation.

bullion, still the only one that caused any serious trouble was lead, which was reduced by the action of the pans and amalgamated as readily as the silver itself. A noticeable feature in regard to the basing of this bullion was, that it became serious at the same time that wulfenite appeared in considerable quantities in the ore. Whether this mineral was the prime cause of the trouble I am not prepared to say; but we did not have the same difficulty when the percentage of lead was much higher in the ore, but in the form of cerussite or galena.

The ore was crushed through a screen corresponding to a 35-mesh wire cloth, and subsequently ground for one hour in the pans. By giving up the grinding in the pans, and by using finer screens in the batteries, but little of the lead was taken up;* and by the use of lime, etc., in cleaning the amalgam, as already described above, the bullion was brought up to .970 fine; the remaining base, being principally copper, resulting from the bluestone used, was not of sufficient importance to extract. The extraction of copper, even after it has been amalgamated, presents no difficulties, as has been successfully demonstrated on a working scale at the tailing mills on the Carson River.

The ores of the Tombstone district carry a varying amount of gold, which in some cases is visible; but in others it only makes its presence known by the assays. At Charleston it is not positively known in what form this metal occurs, as it is never visible. Assays for the first six months of this year show that only 43 per cent. of the total gold value of the ore was saved. This value, however, rarely reaches two dollars to the ton. The amalgam is retorted in 15-inch top-discharge retorts. About 4 cords of willow wood are consumed to the ton of amalgam. The firing lasts five hours, and the charge varies from a ton upward.

For bullion averaging .938 fine the loss by volatilization and skimming averages 7.55 per cent., and the time required averages three hours, twenty-one minutes. The average weight of the bars is 2711 ounces, which require 43 pounds of charcoal and 20 pounds of coke. The average cost of milling for the past five months has been $4.90 per ton. This amount was subdivided as follows:

* The experience of a former management was very similar; when grinding was carried on two hours, the bullion sank to .200–.300 fine, and even lower. By crushing finer and not grinding at all, it rose in a day or so to .900 fine and over. By grinding one-half hour it was kept at .850 fine.

COST OF MILLING.

Fuel,	$1.05
Chemicals (including quicksilver),	0.77
Lubrication,	0.04
Illumination,	0.03
Castings,	0.33
Supplies,	0.16
Labor,	2.52
Total,	$4.90

COST OF LABOR IN REDUCING ONE TON OF ORE.*

Crushing,	$0.52
Amalgamation,	0.67
Power, pumps, etc.,	0.47
Foreman, etc.,	0.87
Tailings pit,	0.11
	$2.64

The loss in quicksilver to the ton of ore milled varies according to the grade and character of the ore, but averages about 1.3 pounds. About 0.11 cords of wood and 1200 gallons of water are consumed to the ton.

A NATIVE PROCESS OF SMELTING COPPER ORES IN THE STATE OF JALISCO, MEXICO.

BY WALTER B. DEVEREUX, E.M., GLOBE, ARIZONA.

METALLIC copper is a product of native metallurgy in various parts of Mexico, and by somewhat varied processes. While recently examining copper mines in the State of Jalisco, I had an opportunity of witnessing Mexican copper smelting by a process which I have not seen described, and which is interesting from the fact, that a fine quality of copper is produced from sulphurous ores in three metallurgical operations, and apparently without excessive loss. The process was carried on in buildings which were part of a plant erected by an American more than twenty-five years ago for the purpose of smelting and working copper. After a few years this man met with accidental death, and the works have been but little used since. Located in the centre of a high range of mountains, far from any town or seaport, and inaccessible except over difficult mule trails, these substantial buildings, filled with furnaces and heavy machinery,

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* This table has reference simply to a single month's run, or, what is the same thing, to the working of 1730 tons of ore.

Arizona

ANNUAL REPORT

ON THE

MINES AND MILLS

OF THE

TOMBSTONE MILL AND MINING COMPANY

WITH PRODUCTION AND EXPENSES,

FOR THE YEAR ENDING MARCH 31, 1883.

BY

JOHN A. CHURCH,

SUPERINTENDENT.

PHILADELPHIA:
McCALLA & STAVELY, PRINTERS,
237-9 Dock Street.

Office of the Tombstone Mill and Mining Company,

432 WALNUT STREET.

Philadelphia, April 30th, 1883.

To the Stockholders of the Tombstone Mill and Mining Company:

We transmit herewith the regular Annual Report of our Superintendent, showing in detail the results of the operations at our Mines, Mills and Furnace for the year ending March 31, 1883; together with a comprehensive and clear description of their present condition and future prospects.

We do not see that there is anything to add from this office regarding the property and business of the Company in Arizona, beyond saying that we expect an early decision by the Supreme Court of that Territory in our suit against the Way Up Mining Co.

The consequences of the unexpected and extraordinary decision rendered by the lower court in that case shortly after the issue of our report of a year ago, so occupied our officers at distant points, that the stockholders' meeting at the time contemplated was impracticable. The same cause delayed the definite solution of the problem of the utilization of our Mill tailings, the result of which was to have been considered at that meeting in connection with the offer of certain parties to purchase them in a body. That result is, however, so highly satisfactory, that the Board cannot now entertain such a proposition even to obtain so desirable an end as the *immediate* extinguishment of the Company's debt.

The total receipts of the Co. for the year, April 1, 1882 to March 31, 1883—		
from Silver, Gold and Lead bullion amounted to.		$658,327 69
from supplies furnished Tributers, Contractors and Miners		5,000 89
		$663,328 58
The expenditures at Mines—detailed in Superintendent's Report—		543,926 69
Net profit of year's operations at the Mines		$119,401 89
Of the total expenditure, there was invested during the year—		
In new permanent plant.	$24,560 83	
Mining Claims on side lines	6,400 00	
Excess of supplies on hand, March 31, '83, over April 1, '82.	20,032 64	$50,993 47

In no year in the history of our Company has the management been required to deal with so many of the drawbacks incident to mining for the precious metals, and had not a relative as well as a positive increased economy been effected during the year, its operations might have resulted in a loss instead of the profit shown by the preceding statement.

The Superintendent has described how we were, by the decision already referred to, cut off from following the rich ore in the Goodenough lode across our side lines, and thrown back upon the ore within the lines, which had so seriously run down in grade. An explanation in detail will be found on pp. 15–16 of his report, in which connection it will be observed that the closing quarter of the past year brought back the average yield and profit per ton to about that of the preceding year.

The following comparison of the results of the operations of the last two years, while showing the cause of the decreased production in the second year to have been the low grade of the ore worked, shows also the great reduction effected in that year in the cost of mining and milling:

	ORE MILLED.	PRODUCT.		EXPENSES.	
	Tons.	Total.	Per ton.	Total.	Per ton.
April 1, 1881, to March 31, 1882...........	29,212	$1,337,361	$45.78	$700,412	$23.96
April 1, 1882, to March 31, 1883...........	21,474	603,265	28.09	430,449	19.86

In addition to our profits being diminished by thus being compelled to work such low grade ore, we were under the necessity, while incurring heavy legal expenses, of purchasing additional concentrating machinery, building a furnace, and erecting new hoisting apparatus for working our West Side Mine now becoming so productive. It thus became necessary to increase the Company's debt before its reduction could be entered upon, and the reduction, so far as it has been effected, has been the work of the latter half of the past year, and it has been contributed to by both Mill and Furnace. Twenty-five thousand dollars were paid on the debt from the net profit of the Mill last month; an equal amount from the net product of the Furnace the preceding month; and thirty-five thousand dollars were previously paid from the combined profits of Mill and Furnace.

The total *gross* debt of the Company when the last circular to stockholders was issued, April 29, 1882, less cash on hand (no other asset being deducted) was....$401,951 09

The total *gross* debt on the 1st day of April, 1883, less cash on hand (no other asset being deducted) was...............................$355,353 02

As all the debt with the exception of the advances made by our San Francisco Bank, had been assumed by members of the Board, an arrangement was made on the 1st of July, 1882, with all the creditors excepting the Bank, for an extension of one, two and three years, and Bonds bearing six per cent interest were authorized to the extent of $446,000, all of which have been issued at par in payment of principal and interest to April 1, 1883; of which $85,000 have been redeemed and cancelled; leaving Bonds outstanding payable in 1883 $115,000, in 1884 $116,000, in 1885 $130,000, amounting to $361,000, with interest to date of payment.

The Company has no floating debt, as all current expenses are paid monthly, and this $361,000 was therefore the total *gross* debt on the 1st of this month, no deduction being made for assets, of which the supplies on hand alone amount to $48,697.46.

There are unascertained *liabilities* consisting of taxes; legal expenses and costs connected with our litigation; and *possible* liability on injunction bonds given by resident real estate owners, in obtaining restraining orders from the Court against the Way Up Mining Company removing ore from the Goodenough lode; all of which are provided for by a Company bond made to a Trustee in the sum of $25,000. This amount is far beyond what the Company would in any reasonable probability be called upon to pay even in the event of losing the whole case, and should we gain it, more than double that amount will be coming to us for ore removed from the Goodenough lode before the restraining order was obtained.

The balance due the Bank in San Francisco, has been reduced to $25,000, which we expect to pay before the 1st of July next, the day on which the Company makes up its yearly financial statement to be recorded with the Secretary of State of Connecticut and town clerk of Hartford, as required by the Incorporation Law under which we are organized. As soon as practicable after its preparation this year the stockholders will be called together in Connecticut (where they are required to meet) and the statement submitted, at which time we hope to be able to report some definite determination of the Company's litigation with reference to the Goodenough lode.

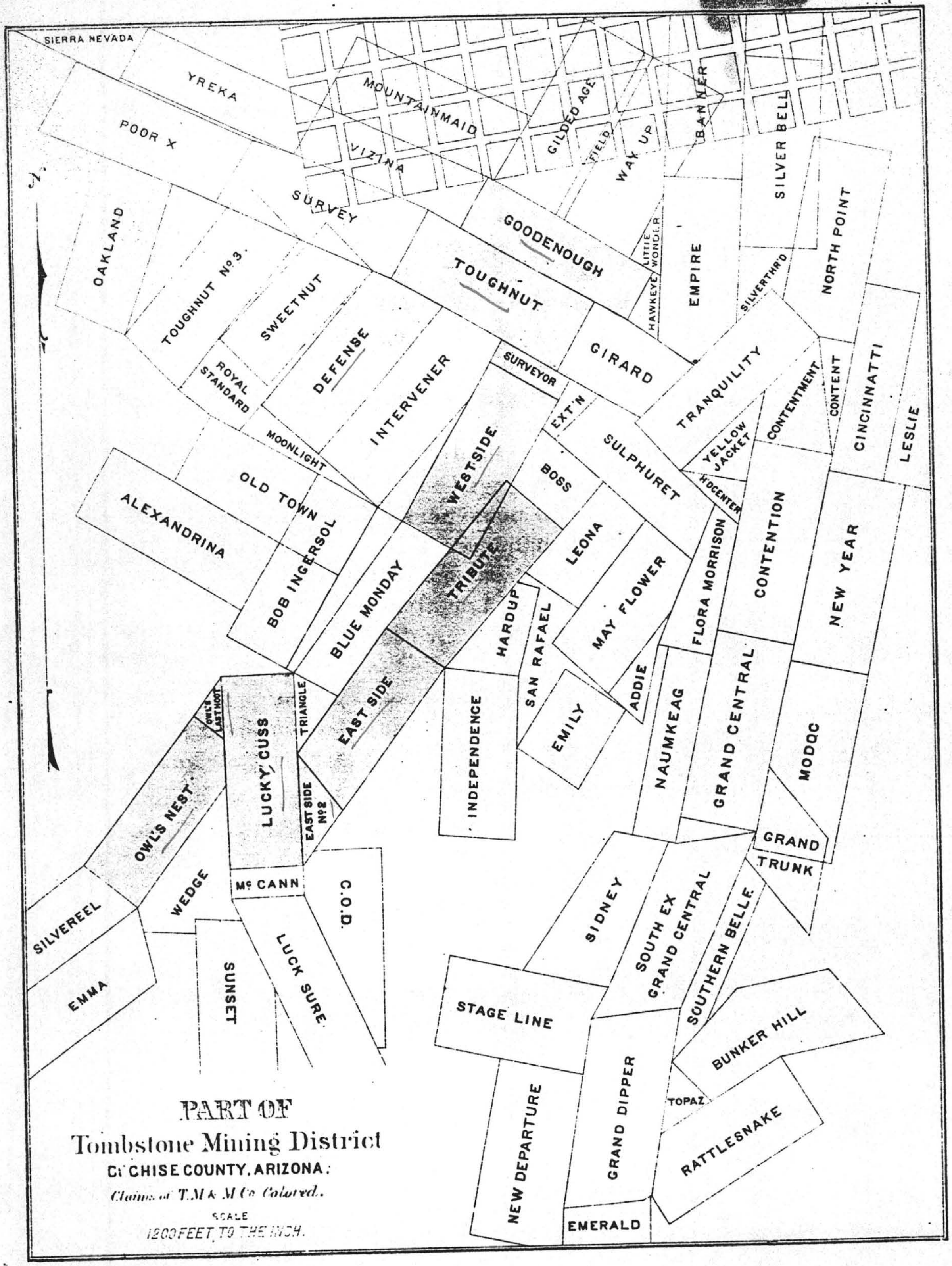
It will be seen from the Superintendent's report and the financial results of the operations of the furnace during the past year, that the reliance of the Directors upon the accumulations of mill tailings for the payment of the Company's debt has been fully justified. While the number of tons of tailings treated during the year has been less than anticipated, owing to the delays incident to the starting of a new business, and securing supplies in a country where no such business had been heretofore conducted, the profit gained per ton has been beyond our expectations, and now that this business has been placed on a working basis, it is hoped that the monthly output from the furnace may be large and regular.

It will also be seen from the report that, as a result of the running of the furnace thus far, the Superintendent expects to realize a net profit of over $600,000 from the tailings *now* on hand (in connection with manganese ore from Lucky Cuss Mine), and they are accumulating at the rate of over a thousand tons a month. Even should his anticipations not be fully realized, no reasonable doubt can now exist that the tailings will more than pay the debt still resting upon the Company, to the extinguishment of which, at the earliest possible day, the Directors are bending their most earnest efforts.

By Order of the Board of Directors.

GEORGE BURNHAM,
President.

W. J. CHEYNEY,
Secretary.



PART OF
Tombstone Mining District
COCHISE COUNTY, ARIZONA.
Claims of T.M. & M. Co. Colored.
SCALE
1200 FEET TO THE INCH.

SUPERINTENDENT'S REPORT.

The product from April 1, 1882 to March 31, 1883, was:

Ore mined	21,991·02 tons
Ore milled	21,474·00 tons
Fire-clay and limestone mined for furnace	60·67 tons

The mill produced:

Number of Silver bars	232
Crude Bullion (Mint weight)	642,830·02 ounces
Fine Silver	532,372·03 ounces
Fine Gold	1,813·00 ounces
Base metal	102,823·82 ounces
Market value of Silver (deducting discount, freight and shortage)	$565,790 67
Market value of Gold	37,474 71
Total	$603,265 38
The furnace produced	2708 bars
Containing fine Silver sold	40,883·57 ounces
Containing fine Gold "	298·81 ounces
Containing Lead "	263,333·00 pounds
Market value of furnace product deducting freight and charges	$55,062 31
Base Bullion on hand	6,000 00

The total marketed product of the year's work is:

Silver, 573,255·60 ounces	value,	$609,960 85
Gold, 2,111·81 ounces	value,	43,487 93
Lead, 131·67 tons	value,	4,878 91
		$658,327 69

The returns given from base bullion are exact, but *all* expenses of freight, refining and marketing are charged against the lead, leaving the silver and gold to be returned at their full market value less about 5 per cent for loss in treatment.

With the deduction of 16 per cent, the milling ore, which also represents the product of the mines separate from the product of the tailings, has had an average value as follows:

	Ounces.	Currency.	
Gross value of ore per ton Silver	32·19	$34 92	
Gold	0·18	3 72	
			$38 64
Yield per ton Silver	24·71	$26 81	
Gold	0·084	1 74	
			$28 55

Percentage extraction of Silver, 76·76; Gold, 46·67; Average, 73·88.

The percentage of extraction varies slightly from that given in the mill accounts as the latter is calculated upon mill assays, which vary slightly from mint returns.

Mint returns by months are shown in the following table, March being estimated. At the mint the bars are remelted, and suffer a certain loss in weight. The official assays also differ from our own, and the differences in results on the year's work are:

	Mill Assays. Ounces.	Mint Returns. Ounces.	Difference. Ounces.	Difference. Per cent.
Crude Bullion	641,978	637,008·85	— 4,969	— 0·77
Fine Silver	528,946	532,372·03	+ 3,426	+ 0·64
Fine Gold	1,821·99	1,813·00	— 8·99	— 0·49

The accounts with the Anglo-Californian Bank show the following gains and losses in selling our bullion, March not being included:

Shortage on Bars, $1,989 85 Gain, $267 87 Nett shortage $1,721 98

BULLION PRODUCT.

April 1st, 1882, to March 31st, 1883.

(BY MINT RETURNS.)

	Number of Bars.	Gross Weight, ounces.	Silver, ounces.	Gold, ounces.	Base Metal, ounces.
April, 1882	40	112,864·30	75,258·24	257·58	37,348·48
May	30	76,017·30	35,631·71	102·55	40,283·04
June	18	49,140·70	47,649·62	42·39	1,448·69
July	20	54,020·90	51,154·01	50·08	2,816·81
August	15	42,021·90	41,146·04	50·64	855·22
September	18	49,357·35	48,755·54	97·04	474·77
1st 6 months	141	383,422·45	299,595·16	600·28	83,227·01
October	16	44,983·10	43,551·95	163·42	1,267·73
November	16	43,032·00	38,297·24	202·00	4,532·76
December	14	39,717·50	35,364·61	157·83	4,195·06
January, 1883	12	34,449·10	30,072·01	169·45	4,207·64
February	14	38,845·70	36,375·10	219·55	2,251·05
March	19	52,559·00	49,115·96	300.47	3,142.57
	91	253,586·40	232,776·87	1212.72	19,596·81
Total for year	232	637,008 85	532,372·03	1813·00	102,823·82

Average fineness, Silver	835·74
" " Gold	2·85
Percentage, Base Metal	161·41
	1000·00

In addition to the kinds of ore mined in previous years, the mines have latterly been called upon for manganese, lime and fire-clay for furnace use, all of which are obtainable in any needed quantity and of excellent quality. The ore mined by tributers belongs to the Goodenough and Toughnut mines exclusively, and in about equal proportions. This table is an epitome of the mining history of the different claims, and shows clearly their varying fortunes.

ORE PRODUCTION.

April 1st, 1882, to March 31st, 1883.

	Main Works. Tons.	Combination. Tons.	West Side. Tons.	Lucky Cuss. Tons.	Defence. Tons.	Northwest. Tons.	Total.
April, 1882........	1,211·67	1,393·12	61·55		......	144·06	2,810·40
May..............	1,187·72	1,390·84	53·02		......	143·28	2,774·86
June..............	108.23	1,469·21	177·32		......		1,754·76
July...............	104·02	1,522·05	257·46		......		1,883·53
August............	367·75	1,334·53	198·57		......		1,900·85
September.........	366·52	895·81	533·08	78·20	......		1,873·61
1st 6 months.....	3,345·91	8,005·56	1,281·00	78·20		287·34	12,998·01
October...........	504·65	460·03	746·87	148·84	......	Limestone	1,860·39
November.........	481·70	463·04	764·58	164·53	50·00	and Fire-Clay.	1,923·85
December.........	494·21	373·95	766·17	152·83	Tribute.	11·05	1,787·16
January, 1883......	336·32	61·80	635·90	133·00	......	37·50	1,167·02
February..........	230·37	63·20	570·30	17·35	50·78	12·12	932·00
March.............	257·48	45·68	768·90	185·53	65·00	......	1,322·59
2d 6 months.....	2,304·73	1,467·70	4,252·72	802·08	165·78	60·67	8,993·01
Total for year....	5,650·64	9,473.26	5,533·72	880·28	165·78	348·01	21,991·02

The whole record of the Company and its predecessors in the mining of ore and production of metals is as follows, the table including only the marketed product:

	Tons Ore.	Gold, oz.	Silver, oz.	Lead, Tons.
June—September, 1879...............	2,025·00	284·86	129,215·81	......
October, 1879—March, 1880..........	3,733·00	450·60	137,375·06	......
April—September, 1880..............	7,242·00	745·70	392,017·11	......
October, 1880—March, 1881..........	9,363·05	1099·42	474,831·77	......
April—September, 1881..............	12,229·08	1275·54	607,232·26	......
October, 1881—March, 1882..........	16,982·58	1187·30	590,886·56	......
April—September, 1882..............	12,998·01	600·28	299,595·16	......
October, 1882—March, 1883..........	8,993·01	1212·72	232,776·37	131·67
	73,565·73	6856·42	2,863,930·70	131·67
Average extraction (in mill only)......		0·093	38·35	

The above total weight of silver is about 98⅕ tons, avoirdupois. In proportions, the silver is 0·0013 of the weight of ore, and the gold is 0·0000039.

By legal value (the only valuation that has been permanent during the working period) this ore has produced per ton,

Silver	$50 29
Gold	1 92
	$52 21

Probably the ore actually contained about 19,000 ounces of gold and 3,811,000 ounces of silver; worth at legal valuation, $72.40 per ton.

The difference between the gross quantities mentioned is in round numbers 12,000 ounces gold and 950,000 ounces silver, representing nearly $1,300,000 that are or should be locked up in the tailing beds. One of my principal labors since I took charge of the Company's Mines and Mills has been to rescue this large property from its present waste condition, and this work has culminated during the last year.

A concentration mill has been built and worked with great success, and a furnace has been built and worked with sufficient success to pay all expenses of both these enterprises and to give assurance of a steady and valuable output when improvements now under way shall be completed. The material treated has been the tailings which have lain waste for years, and in utilizing them another product of the mines, argentiferous manganese, heretofore almost as useless as the tailings, has been made productive.

In another part of this report it is shown that, taking the actual results of the past as a basis of computation, the concentration and smelting of the present accumulation of tailings should give a profit of at least $660,000. About one-tenth of this has been realized, and preparations are now making to obtain the remainder with more rapidity. These preparations consist in the introduction of new machinery to treat both the old tailings and those of our daily make. For the latter purpose machines will be placed in the Corbin Mill. At present these plans merely look to the extension of the works sufficiently to keep the furnace running with regularity.

It will be noticed that the proportionate loss of gold in amalgamation is greater than of silver. Concentration of the tailings should accordingly recover a greater percentage valuation of the gold than of silver, and experience shows this to be the fact.

Another of the leading events of the year is the practical transfer of mining work from the Goodenough and Toughnut to the West Side mine, and the rise of the latter to the position of the most promising mine in Tombstone District. At present the two mines first mentioned are almost idle, after yielding nearly 67,000 tons of ore and probably ninety-five per cent of all bullion the Company has produced. The reasons for this change of operations are twofold:

In May, 1882, the case of this Company against the Way Up Company was decided against us, and though an appeal was taken, and has been argued, no decision has been reached yet, and operations on the Goodenough mine have necessarily been controlled by the first decision.

The Way Up mine adjoins the Goodenough, in such a position as to intercept 600 feet of our vein as it dips into the earth. The result of the suit not only deprived us of about $100,000 worth of ore, but prevented us from following our vein beyond our lines in a part of the claim, and made it imprudent to do so in the remaining part. All the *known* ore bodies in the Goodenough have been exhausted, and most of the ground within the claim has been prospected, leaving our future almost entirely to the finding of ore within our vein, but outside of our surface lines, where the law allows us to search for it.

The stoppage of work on the Toughnut was due to very different causes. Like its neighbor, the *known* ore bodies in this claim are exhausted, and little ground remains unprospected within our lines, but the dip of the ore is protected by the Defence and Survey, two claims belonging to this Company, and legal complications are not looked for.

But neither of the two mines on the Toughnut claim was well opened. The Northwest never had permanent works, and the main shaft at the other end of the claim was badly planned. The expense of prospecting became so heavy that it was decided to take advantage of the favorable position of the Survey and Defence and utilize them to prospect the Toughnut. The West Side vein which runs through the former has been opened with great success, and some work has been done on the Defence, which will very soon be attacked more vigorously.

As yet the Toughnut has not been reached from the West Side, because the independent development of the latter has been so successful, and perhaps no effort will be made to reach it until another level is opened, but the ore in the latter mine works in such a way as to show the wisdom of the general plan adopted.

I do not believe that either the Goodenough or Toughnut is exhausted, but am strongly of opinion that the ore bearing formation is productive below the depths we have reached. Our deepest level is only 268 feet deep in the Toughnut, and 300 feet in the Goodenough, and the formation is not one that lies level, but dips with considerable steepness, probably thirty degrees at least. The condition of the deepest working on the West Side almost demonstrates the continuance of ore to a greater depth than we have yet reached in the Toughnut, and I believe the future work will reveal important ore bodies lying between the center of the West Side claim and the Toughnut side line.

The condition of the mines, mills and furnace as they are at present, and their operations during the year are shown in the following special sections of this report.

THE MINES.

The Company owns eleven claims, some being of small extent. Nine have been patented, and two have been surveyed, advertised and entry made, so that in effect the entire property is in fee simple with undisputed title. A full claim contains 20⅔ acres, and the areas given in the following table show the proportionate size of the different claims, the areas being taken from the official surveys:

	Acres.	Character of Title.		Acres.	Character of Title.
Goodenough	15·72	patent	East Side	16·90	patent
Toughnut	20·66	patent	East Side No. 2	2·57	entry
Survey	1·80	patent	Lucky Cuss	20·56	patent
Defence	20·33	patent	Owl's Nest	20·11	patent
West Side	20·50	patent	Owl's Last Hoot	4·46	entry
Tribute	17·80	patent	Total area	161·41 acres.	

The claims form a continuous chain of adjoining properties stretching from north to south in the order given, for more than a mile. The Goodenough, Toughnut, West Side and Lucky Cuss have proven themselves valuable ore-bearing ground. Ore has been sent to the mill from the Defence, Tribute and Owl's Last Hoot, the Survey is known to contain a promising vein, and ore has been found on all the other claims.

The present condition of the mines in detail is as follows:

GOODENOUGH.—This has been the most productive property of the Company, having yielded about 41,500 tons of rich ore since it was first opened in 1879. The ore is found in two separate collections of ore bodies, one at each end of the claim, that at the East end being known as the Main works, and that at the West end being called the Combination and Number Six. In each place there were four large bonanzas. As near as can be ascertained at the present time the product has been:

From Combination ore bodies (2)	25,088 tons.
Number Six " (2).	3,500 "
From Number 2 Incline (East End)	3,000 "
" 1 " Upper ore body	3,000 "
" " Middle ore body	6,000 "
" " Lowest ore body	1,000 "
	41,588 "

The ground in which these ore bodies immediately lay is now nearly exhausted, about 4800 tons having been taken from them during the year past. But the ground in the center of the claim has not been prospected, and this work will be undertaken soon.

At present all the openings, except one, in this mine have been carried to the side line, and further exploration in depth must be made outside of the surface lines of the claim and under adjoining properties belonging to other owners. Work is still going on in the old excavations, and may continue for months, but in a small way.

TOUGHNUT.—This claim has had five ore bodies, all lying within the surface lines of the claim. Of these:

The Quarry has yielded about	1,500 tons.
88 foot ore body about	2,200 "
130 foot ore body about	5,500 "
180 foot ore body about	8,000 tons
North West mine	7,500 "
Total	24,700 "

Here the ore has not been carried down to the side line at any point, but has crossed the East end line. From the large outcrop on the surface at the quarry a chute of ore continued down to the 256 foot level dipping both toward the south side line, and the East end line. This chute was crossed almost at right angles by two flat ore bodies, the 88 foot and 130 foot. At the lower termination of the chute, the grade of the ore is quite low, and though this does not establish the failure of the ore body, a similar state of things having existed between the 88 foot and 130 foot bonanzas, the disappearance of milling ore made every work of exploration onerous. Accordingly the task of exploring the Eastern end of the Toughnut was transferred to the West Side, a claim which abuts upon the former mine directly opposite this productive ground. Exploration in depth has ceased, therefore, within the Toughnut claim, as a similar state of things is found at the West end of the claim where the Defence mine lies upon the dip of the ore. Legal complications are not to be feared in the Toughnut, as all the known productive area of the vein is guarded by the Survey and Defence claims.

The greatest product of this mine was obtained between November, 1881, and June, 1882. Since the latter date the yield has been small, and mostly from bunches of ore near the surface, and passed unnoticed by the former management. As in the Goodenough the extreme ends of the claim are ore-bearing, and the central portion unexplored.

West Side.—This mine is now the most promising claim of the Company. It lies nearly at right angles to the Toughnut, is 1496 feet long, and has an extension 140 feet long in the Survey, which abuts upon the Toughnut. Vein croppings run almost continuously through the ground for a length of 1300 feet.

Three shafts known by numbers have been sunk on the vein, and are connected by drifts underground. No. 1 is 523 feet north of the South end line of the claim; No. 2 is 470 feet further north, and No. 3 is 232 feet north from No. 2. Drifting on the vein extends 230 feet south from No. 1 and 180 feet north from No. 3, so that the vein is opened for a length of 1210 feet.

Ore is found through nearly the whole of this distance, some-

230 & 238

times in a thin vein or in bunches, sometimes in continuous bodies from 100 to 200 feet long, and 2 to 10 feet thick. The greatest thickness yet opened is on the 3d or lowest level.

Owing to the character of the vein, it has been found advisable to open levels at successive depths of 75 feet, so that the 3d level is 230 feet below the surface, and 238 feet below the timbered mouth, or "collar" of No. 3 shaft. This level is also 72 feet above the 3d level of the Toughnut, and it is intended to carry this or the 4th level northward to a connection with that mine.

The West Side vein crosses a gentle hill, and rises to the crests of two adjoining hills, and the principal ore chute lies in the central elevation. There are signs that each one of these hills will carry its separate important ore body, the different masses being connected by smaller bunches and thin veins of ore. This central hill contains shafts Nos. 2 and 3.

Most of the mining already done has been in the central mass, which appears to be about 180 feet long, and from 1 to 10 feet thick, with occasional cross-veins running for 20 feet east and west. It stands in the vein with an inclination northward, the vein itself running north and south, and dipping slightly east. This bonanza reaches from the surface to and below the 3d level, and its croppings cover the whole space between Shafts Nos. 2 and 3.

The work of opening the 3d level between these shafts was finished in March last, and sinking was immediately resumed, and is now 25 feet below that level. The ore continues throughout this depth, and has been opened on the 3d level for a length of 85 feet.

Since the West Side was opened, the bullion made has increased materially in gold. In general the grade of the ore is not remarkably high, though it is good, and seems to be improving in depth. In fact, the ore itself is of excellent grade, quite as good as anything ever mined by the Company, but much of the rock that lies next it is so loose and crumbling, that it is impossible, in a vein of the dimensions given, to keep the ore clean. As sent to the mill the ore probably contains about 40 ounces silver, and ½ ounce gold, and is worth in legal value $63, and in market value about $54.58 per ton at current rates.

At present the prospects of this mine are very bright. There appears to be in the mine at least one-half more ore than was taken from it during the last year, or say 8000 tons. The ore mills well and if large ore bodies are found, the mine will be the cheapest to work of all the Company's properties, the rock being much easier to work than in the Goodenough or Toughnut. Hitherto the thinness of the vein has made the work costly.

SURVEY.—This mine is the northern extension of the West Side, connecting that claim with the Toughnut. It has only a 50 foot shaft, and no work is done in it, the expectation being that its vein will be opened from the West Side works. As there is another mine of this name in Tombstone, this one is usually called the Surveyor.

The DEFENCE is parallel to the West Side, and lies at the western end of the Toughnut, as the Survey lies at its eastern end. As these claims are 600 feet wide, while the Toughnut is 1500 feet long and the Defence overlaps the latter, there is space between the Defence and West Side for another claim, called the Intervenor, not owned by this Company.

Some work has been done on the Defence, and ore extracted. This work, which is not sufficient to establish the character or extent of the vein, is now in progress. The mine has yielded about 50 tons to the Company and 25 tons to tributers.

TRIBUTE.—This claim lies nearly parallel to the West Side, and partly overlapping it. A shaft 100 feet deep has been sunk on it and some ore removed, but continuous bodies have not been found, and no work is in progress there.

EAST SIDE and EAST SIDE, No. 2, are a continuation of the Tribute. At the south end of the former, and on the latter, considerable work has been done, resulting in the extraction of about 70 tons of ore, not of high grade and containing a considerable quantity of manganese. In fact, this is the beginning of the manganese area in the District. The ore is not so well fitted for furnace use as that found on the Lucky Cuss, and no work is done there at present. The vein, however, which starts in the East Side, continues entirely across the East Side, No. 2, and into the Lucky Cuss, where it has been mined with profit.

Lucky Cuss.—This is the seat of large deposits of silver bearing manganese ore, which is now mined as a flux for use in the furnace. Two lines of these deposits are known. That on the north end appears to be a continuous vein, while in the southern line the ore bodies are entirely separated from each other, though they appear to lie in two definite directions. The ore is quite a pure and rich oxide of manganese, containing about 10 per cent of silica and 25 ounces of silver. As one half the smelting charge is manganese, this flux affords quite an important supply of precious metal. Probably 10,000 tons of the flux will be needed with the concentrates that can be made from the tailings now on hand, and there is every prospect that the Lucky Cuss can supply it. So far only 880 tons have been mined.

The Lucky Cuss was one of the first mines to be opened in Tombstone, and the resumption of operations upon it has been matter for congratulation in the camp.

The country rock is a hard white limestone, in which the manganese occurs in chutes, which have a small horizontal section but appear to be quite persistent vertically. A depth of 100 feet has been reached in three places, and in all the ore is continuous from the surface. In one it forms a cylindrical body, 10 to 12 feet in diameter, in another it is lense-shaped and about 3 by 40 feet in section, and in the third the ore body is longer.

Small bunches of galena and carbonate of lead occur in the manganese, and these are always rich, usually running up to 200 ounces silver per ton. With the manganese the rule is that the richer in silica the richer also in silver, though we have sometimes had a mixture of manganese and lime spar that was richer than the average. The richest ore is too siliceous to serve as a flux and too manganiferous to mill well, so that we are able to use it only with great slowness.

All the work done in the claim is in preparation for the extraction of ore, and as this is the most expensive part of mining, the cost has been temporarily high. So far the ore has cost $10.13 per ton, but when the ore now uncovered is removed, the cost per ton will be much less.

Owl's Nest and Owl's Last Hoot are also two continuous claims lying nearly parallel to and the former overlapping the Lucky Cuss. They form the southern termination of the Company's property. They are interesting mainly from the fact that they cover the contact between granite and limestone, a situation that is usually favorable for ore deposition. We have some shafts in the granite and some in limestone, but neither has yielded rich ore or much of it, though a similar situation on a claim further south has been productive.

Tributing.—During the year renewed attention has been given to tributing, or the extraction of ore upon royalty by men not in the Company's employ, and 115 tons have been mined in this manner, besides about 50 tons not yet delivered. The royalty paid is one-third, except in two cases, where one-quarter was accepted for special reasons. Part of the ore was paid for in bulk, and part was worked in the Company's mill, the royalty being taken from the proceeds. Part was smelting ore and has not been utilized yet.

In spite of a desire to encourage work of this kind, I have found, for the second time, that the Company gains little by it, and prefer to test the small detached bunches of ore that in this country lie scattered over the surface, by working a few careful men upon them.

In mining work nothing new has been introduced, except the sinking of the new No. 3 shaft at the West Side. This work, with its new hoisting engine and ore bin has already been very advantgeous. It is now my intention to connect No. 1 shaft on that vein with the 3d level, and it is possible that this shaft may be used for hoisting. If so, the West Side claim will be divided into four nearly equal parts, marked off by three shafts, of which one will be about 530 feet from the south boundary, one about 700 feet from the north end of the Survey claim, and the third in the centre.

On the Goodenough, Toughnut and West Side five steam hoists are placed, and the Lucky Cuss will have a horse whim, which will be sufficient for its needs. A force of 125 men is employed in the Company's mines, and when the furnace is running, the reduction of the ore employs, in milling and smelting, about 60 men.

At all points of extraction a well tried system of handling the ore has been introduced. Bins, holding from 40 to 500 tons, are built at each hoisting shaft, and large enough to allow the large ore wagons to load from them without shoveling. The cover of the bin forms a sorting floor, to which the ore from the mine is dropped, first running over a screen which separates the fine stuff. The coarse ore is picked over by hand, and the waste removed.

This is a costly work and also causes some loss, but the distance of the mill and the cost of hauling make it necessary and profitable.

EXPENSES.

In the following statement the expenses of mining and milling are shown in detail. The item of "outside mining" refers to the cost of extracting a quantity of smelting ore from a vein near the mills, on property not belonging to the Company.

MINING (21,903 TONS).

	Total.	Per ton.
Labor	$190,531 00	$8 70
Contract	4,372 10	0 20
Supplies	34,703 48	1 58
Repairs and renewals	980 60	0 05
Ore hauling (21,064.85 tons)	63,204 65	3 00
Total	$293,791 83	$13 53

MILLING (21,474 TONS).

	Total.	Per ton.
Labor	$56,367 84	$2 62
Supplies	47,152 97	2 19
Repairs and renewals	2,506 08	12
Total	$106,026 89	$4 93

CONCENTRATION.

	Total.
Labor	$9,672 40
Supplies	873 13
Total	$10,545 53

FURNACE.

	Total.
Labor	$7,529 60
Supplies	23,353 63
Lucky Cuss mining (Manganese)	9,665 56
Outside mining	379 62
Ore purchased	3,752 13
Ore hauling	3,640 18
Bullion hauling	263 89
Total	$48,584 61

SUNDRIES.

	Total.	Per ton.
General expense	$8,367 51	$0 38
Administration	22,262 84	1 02
Total	$30,630 35	$1 40
Grand total of mining, milling, and sundries	$430,449 07	$19 86

EXTRAORDINARY.

			Per ton.
Legal expenses	$15,827 49		
Mine construction	8,847 70		
Mill construction	2,188 15		
Furnace construction, including concentrators	13,524 98		
Tribute ore	7,559 16		
Adjoining Mining Claims	6,400 00	$54,347 48	$1 90
Total of all expenses		$543,926 69	

There is now on hand, of supplies by inventory:

			Per ton.
Mine supplies	$4,187 01		$0 19
Mill	9,180 02		0 43
Furnace	29,280 93	$42,647 96	

The record of the year shows a considerable decrease in all expenses which are within control. Mining and milling expenses are $19.86 per ton against $23.96 for the previous year, and including extraordinary expenses the comparison is as $21.76 to $27.16 for the same items. The improvement commenced in the latter half of the first year, and has been carried forward with increasing success. The comparison is fair, with the exception that ten cents per ton should be deducted from the first year's average expense for cost of the first trials in concentration, an item that is not included in the computation for this year.

In the assay office 10,100 assays were made, at a total cost of $2864.62 for labor and supplies, or an average cost of 28⅓ cents. The ore changes constantly in appearance, and a careful watch is kept on all the rock encountered in the vein. A new assay office has been built, which not only relieves the business office from the danger of fire, but is so well arranged and furnished that a great number of assays can be made daily, and the foremen are not obliged to hesitate about throwing work upon the assayer.

The costs of mining, $9.54, are distributed as follows, the list including every servant of the company except the Superintendent:

	Total by classes.	Total.	Per ton.
Mining	$138,551 00		$6 33
Transportation	16,314 75		0 75
Carmen		$12,611 50	
Shovelers		3,703 25	
Hoisting	15,304 75		0 70
Engineers		7,901 25	
Firemen		213 50	
Topmen		6,000 50	
Whim and horses		1,189 50	
Mechanics	10,683 00		0 49
Blacksmiths		6,781, 50	
Toolcarriers		1,417 00	
Timbermen		1,417 00	
Carpenters		1,067 50	
Sorting—Ore sorters	9,454 00		0 43
Surfacemen	2,615 00		0 12
Teamster		1,174 50	
Watchman		1,440 50	
Superintendence	10,412 66		0 47
Assistant Superintendent		3,600 00	
Foremen		2,637 66	
Shift bosses		4,175 00	
Office, surveyor, and bookkeeper	3,323 40		0 15
Assay office, assayer and helper	2,200 75		0 10
			$9 54

THE MILLS.

The reducing machinery of the Company has necessarily followed the fortunes of the mines. Up to June, 1882, thirty-five stamps were at work, but the falling off in ore supply then caused a reduction to twenty stamps, and the failure to find new ore bodies in the well worked ground under the surface of the Toughnut and Goodenough, finally compelled a further reduction to ten stamps. In March, 1883, this decrease was stopped, and fifteen stamps were run nearly all the month, a scale of work which present prospects indicate may be maintained in future.

From 2800 tons a month in April and May, 1882, the ore treated sank in quantity to 1800 tons monthly for the seven following months, and finally to 881 tons in February, rising again to more than 1000 tons in March, 1883.

Fortunately, the yield of bullion did not fall off proportionately to the ore. Indeed, the heavy output of the early months of the year was due to the fact that large masses of low grade ore existed which could be worked at a small profit. The estimated market value of the ore per ton was for the four periods named, \$25.25—\$31.00—\$41.79—\$52.34. On this account the reduction in output and milling has been profitable by reducing expenses materially, while the product did not fall off in the same proportion.

The amount of ore treated by 35 stamps was 5716 tons, by 20 stamps 12,718 tons, by 10 stamps 1877 tons, and by 15 stamps 1163 tons; total 21,474 tons.

No changes of moment have occurred in the mills, except the re-introduction of chemicals, *i. e.*, salt and bluestone in April, 1882, a change in the character of the ore making this step necessary, and the use of sodium amalgam in the last months of the year, in an effort to save a larger percentage of the gold in West Side ore. In this we have been partially successful.

At present the Corbin mill only is running. No concentration takes place there, but machines will soon be introduced for the purpose. At the Gird mill amalgamation has stopped. The furnace and concentrators are situated there. The mill accounts show the following work and results during the year:

Tons ore received at mills	21,186
Tons ore milled	21,474

Average battery assay, ounces	32·19 Silver	0·18 Gold
Average tailings assay	8·01 Silver	0·10 Gold
Average per cent saved	76·07 Silver	44·44 Gold

	Total.	Per Ton Ore.	Per cent.
Pounds (avoir.) amalgam produced	266,026	12·39	
Pounds (avoir.) retort metal	46,888	2·18	
Retort metal ratio to amalgam	1 : 5.67		
Troy ounces retort metal	682,637	31·79	
Troy ounces bars	641,978	29·89	
Loss in melting	40,659	1·90	5·95
Average fineness of bars silver	823·9		82·39
" " " gold	2·8		0·28
Troy ounces in bars silver	528,946·02	24·63	
Troy ounces by assay "	519,010·00	24·18	
Gain over assay "	9,936·02	0·45	1·91
Troy ounces in bars gold	1,821·99	0·084	
Troy ounces by assay "	1,444·52	0·067	
Gain over assay "	377·47	0·017	26·13

These results illustrate one of the peculiarities of work in Tombstone mills, and I believe all the mills in the district have the same experience. Taking the battery assay as the standard of value, and deducting the assay of the tailings, the bullion product is invariably a *plus*, or in excess of the apparent extraction of metal, as shown by the assays. This is the more noticeable with high than with low grade ore. Necessarily, the error is either in too low assays of the battery pulp or in too high assays of the tailings, and probably it is the former, as indicated by our results in concentration, which are a check upon the tailings assays. Repeated efforts have been made in this Company's mills to correct the error, but without result.

The *plus* in gold is still more striking, if the percentage is considered. The gold assays are made once a month from the collected buttons of the daily assays, and as the latter are made upon samples, taken every half hour throughout the year, there is no reason why the samples should not be true averages, especially as all questions connected with the mode of sampling have been carefully considered. There is one source of error which may explain the small *plus* of silver. The sample is taken from the stream of pulp at the end of the battery launder, and as the inclination of this trough is somewhat insufficient, an entirely free flow of the pulp is not secured and the heaviest portion of the ore settles in it, removing a certain part of the richest ore from the sample. This is undoubtedly the source of the error in silver returns, but it cannot explain the remarkable error in the gold, unless there is free gold in the ore heavy enough to settle almost completely in the trough, leaving only the mineralized gold to fall into the sample dipper. Free gold may exist in the ore, but it is not coarse enough to be visible, and it is difficult to see how fine scales should settle so readily.

MATERIALS CONSUMED.	Total.	Per Ton.
Cost of fuel	$22,838 56	$1 06
Chemicals	13,624 79	0 64
Illumination	729 49	0 03
Lubrication	845 02	0 04
Castings	6,757 06	0 31
Hardware	555 62	0 03
Tools	240 42	0 01
Sundries	3,018 03	0 14
Labor	56,892 43	2 65
Total	$105,501 42	$4 91

Quicksilver, pounds	Total,	21,629	Per ton,	$1 00
Salt, pounds	"	110,094	"	5 12
Bluestone	"	22,366	"	1 04
Cords wood	"	2,526⅞	"	0 12
Days' labor	"	13,011¼	"	0 60

The quantity of quicksilver here given is that which was *added* during the year without taking account of what was in the pans in the beginning and end of the twelvemonth, and as there has been a reduction in quantity of ore the amount given per ton is undoubtedly too low.

It has long been my intention to introduce the electric light, but the present cost of illumination, which includes breakage and supplies, hardly justifies the step. The balance between increased cost and risk and increased efficiency of the electric is very close.

TREATMENT OF THE TAILINGS.

When I examined the mines of this Company in the year 1880, the problem of utilizing the tailings had already assumed importance, though only about 15,000 tons of ore had been worked. Now nearly five times that quantity are represented in the tailing beds. The advice then given was to concentrate the tailings and smelt the concentrates with manganese from the Lucky Cuss mine, where important bodies of this ore, carrying from fifteen to thirty ounces of silver per ton, are found.

The plan was beset with difficulties, for the fine condition of the material prevents good work in concentration and hinders smelting, and manganese as a flux though not a positive novelty had not been successfully relied upon, I believe, as the sole dependence of a furnace that has no access to iron either in its ores or flux. But this advice was given for the reason that the remilling of tailings has been almost uniformly a failure, and nothing was to be looked for from this mode of treatment, while concentration and smelting offered a promising though untried field. The result has been a great success, the treatment of about 3500 tons of tailings having paid all the costs of construction and work and a profit besides.

The treatment includes two branches, concentration and smelting, which will be considered separately.

CONCENTRATION.

After preliminary experiments in 1881, six Frue Vanners were obtained from Messrs. Adams & Carter, of San Francisco, and regular work commenced at the end of February, 1882. The records which are summarized in the table given below, cover the whole of the intervening period, or 13 months.

In January, 1883, two revolving buddles or round tables were built, and worked with such success that others have been ordered and will be put in at once.

The problem presented is one of the most troublesome in ore dressing. All the material is in the finest condition, having been reduced to a *maximum* of $\frac{1}{40}$ and $\frac{1}{60}$ of an inch diameter to prepare it for amalgamation, and in this process the ore is ground for hours, not only increasing the proportion of fine slimes, but making the latter sticky by trituration. The greatest loss in concentrating has been due to the fact that these fine slimes run over the table, without yielding their silver. This defect, however, is now cured mostly by the buddles.

The method adopted is as follows: The tailings are thrown into an agitator, where they are stirred with water, and the heaviest sands settle, giving the first concentrated product. The pulp is then run on the Frue Vanners, where a finer concentrate is obtained. After concentrating, the tailings are raised to a buddle, which removes about one-third of the silver still remaining in them. From this buddle the finest material, which still runs off without concentrating, will be delivered to a second buddle of lighter slope, and concentrated there. The buddles have not been running long enough to furnish an estimate of their production.

In this way it is hoped to raise the extraction of gold to a satisfactory point, that portion of the work having always been defective in amalgamation.

The concentrating mill is situated close to the Gird mill, and the distance from the tailing beds has always caused a large expense for wheeling. At present this difficulty has been increased by the removal of the nearest tailings, and the mill will now be moved to the area cleared away in the tailing bed. For this purpose an engine has been provided and the new machinery will be erected at the new point. The purchase of this machinery was made necessary by the fact that the works as first established were not large enough to keep the furnace constantly supplied.

Concentration has now been going on for 13 months, and the whole of this period is included in the table of results given below. The value of the tailings in lead is not determined by daily assays, as the silver is, but the proportion of lead is estimated at 8 per cent.

	Tons.	Assay, per Ton. Silver, oz.,	Gold, oz.	Lead, ℔ ct.	Per cent.
Mill tailings treated	11,467	13·21	0·22	(?) 8·00	
Production,					
From the Agitator	93	52·65	0.48	23·20	
From the Frue Vanners	1483	45·22	9.58	30·90	
Percentage saved by weight					13·31

Weight of Tailings required to make 1 ton of Concentrates, 7·5 tons.
Percentage saved, by value: Silver, 41·29; Gold, 34·09; Lead, 50·61.

COST OF WORKING.

			Tailings.	Concentrates.
Labor	Total, $9,672 40	Per ton,	$0·843	$6 34
Supplies	" 873 13	"	0·076	0 57
Total	$10,545 53		$0·919	$6 81

The extraction of silver in the mill has been about 80 per cent, and of gold about 45 per cent, and the treatment of the tailings increases this by 41·29 and 34·09 per cent, respectively, so that the final results are as follows:

Silver, extracted by amalgamation	80 per cent.
" " concentration, 20×41·29	8·26 "
Total	88·26 per cent.
Gold, extracted by amalgamation	45 "
" " concentration, 55×34·09	18·7 "
Total	63·7 per cent.

These results are not satisfactory, but the improvements in concentration will add probably 4 per cent to the silver and perhaps 12 or even 15 per cent to the gold. If these results can be reached, the whole method of treatment will be in a higher state of perfection than has been obtained heretofore in American milling.

THE FURNACE.

In September, 1882, the building of the furnace was completed and a short trial run was made, which could not be continued, nor resumed for some time, owing to the failure of the coke supply. Afterwards several short runs were made. The fine condition of the materials and the low fusing point of the manganese, combined with the complete absence of sulphur in the charge, caused great trouble. The impurities of the charge collect in the form of a hard lead which separates from the remaining metal and sinks in the lead bath, obstructing circulation and cooling the crucible. The use of manganese as a flux has approved itself, and the Company enjoys the great advantage of using as flux a material that furnishes an important amount of silver and is also mined on their own ground.

To meet the sandy condition of the concentrates, a brick machine has been purchased, and the concentrates will be made into bricks, using fine slimes as binding material. This work has been done by hand and with success, and the machine will undoubtedly improve upon the hand work.

The lead bullion made has been sent to refining establishments in the East. It is of good grade, fair softness, and carries a higher proportion of gold to silver than the mill bullion. As a considerable part of the silver is derived from manganese ores without gold, this proves that the reworking of the tailings will be especially valuable in saving gold.

Four general classes of expenditure are necessary to the working of the furnace, as shown in the following table. The sinking fund charged against construction is not calculated by time, but upon the proportion of tailings that have been worked, and is somewhat high, as no account is taken of new ore that will be concentrated in future. Construction includes both concentrators and furnace.

	Expended.	On hand.	Total.
Construction	$ 603 97	$12,921 01	$13,524 98
Manganese (mining and hauling)	6,046 58	6,810 77	12,857 35
Concentrates and ores	6,043 99	7,927 62	13,971 61
Furnace supplies, hauling and labor	16,522 70	14,542 54	31,065 24
	$29,217 24	$42,201 94	$71,419 18

Among these items, purchased ores and hauling of them, amount to $1889.43, and purchased manganese and its hauling to $2680.03. These expenditures were made in testing the ores of the district, and are not absolutely necessary to the work of the furnace, as the Company has similar material in its own mines.

The furnace work has consumed the following materials:

	Tons.		Percentage of charge.	
Concentrates	438		23·65	
Tailings	438		23·65	
Ore	47·92		2·70	
Manganese	625·25		33·80	
Silver bearing material		1549·17		83·80
Limestone	33·02		1·80	
Slag recharged	260·80		14·40	
Cleanings recharged	6·00			
Fluxes		299·82		16·20
				100·00
Colorado Coke	168·17			
English Coke	81·00			
Charcoal	67·84	317·01		17·15
Total materials	2166·00 tons.			

Production, 2708 bars; 144·88 tons, containing

	Silver, ounces.	Gold, ounces.	Lead, pounds.
In Bullion shipped, 131·95 tons	40,883·57	298·81	263,333
In Bullion on hand, 12·93 tons	4,654·80	34·00	25,537
	45,538·37	332·81	288,870
Market value of Bullion shipped	$44,170 18	$6,013 22	$9,068 52

Total value	$59,251 92
Freight and charges	4,189 61
Net return	$55,062 31

The value of this product is as follows, the return from the bullion on hand being estimated:

Returns from 131·95 tons shipped net	$55,062 31
12·93 on hand	6,000 00
Returns from 93 tons concentrates amalgamated	5,500 00
Total product from re-working tailings	$66,562 31

The portion of concentrates sent to the mill contained more quartz and less lead than the average product. They milled to about 65 per cent of their value, and will be re-concentrated when the Corbin tailing beds are worked.

In preparing the concentrates for the furnace, they are mixed with about half their weight of fine slimes from the oldest bed of tailings. It was hoped that the whole of this bed, which is the richest portion of the tailings, could be smelted without concentration, but its poverty in lead prevents this result. The greatest difficulty experienced in operating the furnace was when the attempt was made to utilize the unconcentrated tailings.

Amalgamation of the concentrates will probably not be resorted to again, and the calculations of future operations may be based upon the furnace work alone. Changes that are necessary in treatment, such as using a smaller proportion of unconcentrated tailings prevent a close reliance upon the results already obtained, but the following figures are probably very near the truth:

Three thousand eight hundred tons of tailings will be concentrated and smelted for $29,217 or $7.69 per ton, and together with the fluxes and ores which will be smelted with them, and the cost of which is included in the foregoing calculation, will yield $61,000 or $16.05 per ton.; profit $8.36 per ton of tailings.

This calculation includes the cost of construction, mining, flux and all accessories, with expenses at a higher rate than they will be in future. It affords a means of estimating the probable value of the tailing beds, taken in connection with the Lucky Cuss mine, and the estimate seems to be faulty only in one respect. The results obtained from the tailings are not uniform. The sandy portions concentrate best, and so far we have treated a better material than we shall treat again until the Corbin sands are reached. On the other hand, the work will improve with experience and attention, and it is assumed these opposite conditions will balance each other.

The value of the tailing beds can be reached in two ways. In the above calculation a profit of $8.36 per ton of tailings is ascertained on the supposition that the proportion of unconcentrated tailings worked with the concentrates will be 1 : 2 in the future instead of 1 : 1 as in the past. This assumption disturbs the result somewhat, but a profit of $8.36 per ton on 72,000 tons is $601,920.

On the other hand, the results actually obtained are these: From 10,417 tons of tailings there was obtained in 12 months 1480 tons of concentrates, or in the proportion 7·08 to 1. Of the concentrates 438 tons, or 29·6 per cent were smelted with an equal weight of tailings, so that the quantity of tailings represented in the furnace product is 438 × 7·08 + 438 = 3540 tons. This yielded $61,000, or $19.61 per ton at a cost of $29,217.24 or $9.42 per ton, and if the whole pile of tailings could be smelted with equal results, it would yield a *profit* of $668,000.

The difference between the two computations shows the influence of silica in the charge, which by demanding manganese to flux it increases the profit. On account of the moderate proportion of lead in our charge we are not able to treat a mixture so siliceous as that given by equal weights of concentrates and tailings and therefore the first and lower computation is the more trustworthy one. Either calculation exhibits clearly the great value of the tailings owned by this Company, a value which is due to the unusually large proportion of lead in its ores as compared with the ores of other mines in this District.

The result obtained fully justifies the advice I have given the Company upon this question. The whole cost of construction, materials used, and labor in concentrating and smelting (to the end of February, 1883), has been $40,692.71, and the returns $66,562.31, so that all expenses have been paid and a substantial profit earned during an experimental campaign made upon only a small per cent. of the tailings available.

A year ago tests were made by milling a small lot of the tailings, but the gross return was only about $1.50 per ton, or say $100,000 for the whole pile. It is worth noticing that by merely stirring the tailings with water and floating off the fine part, a sandy residue has been obtained forming 0.8 per cent of the whole mass of tailings, and yielding in the mill $5500 as shown above. This amounts to 48 cents per ton of tailings, but it is doubtful whether the same proportion will be maintained when the lower portion of the beds where the slimes are most abundant are reached.

JOHN A. CHURCH,
Superintendent.

C.W. GOODALE (1888-9)

before the stripping began. The whole quantity is now awaiting the results of experiments in progress, to determine the details of subsequent treatment. At the present time the material hoisted is almost wholly first-class and lean ore.

THE OCCURRENCE AND TREATMENT OF THE ARGENTIFEROUS MANGANESE ORES OF TOMBSTONE DISTRICT, ARIZONA.

BY CHARLES W. GOODALE, BUTTE CITY, MONTANA.

(Utah and Montana Meeting, July, 1887.)

THE attention of the Institute has been called by Prof. John A. Church* and Mr. W. Lawrence Austin† to the free-milling ores of the Tombstone mines and their treatment, but the silver-bearing manganese ores of the district have received only a passing notice.

As these ores show some interesting peculiarities, and have yielded not less than 750,000 ounces of silver, they are worthy of some study.

The Knoxville, Lucky Cuss, Luck Sure, and Wedge mines (named in the order of their importance) are situated along the northern border of the district. They have been the leading producers of this manganese ore, and possess the same general characteristics. Special attention will be given to the Knoxville, as it has been the one most extensively developed.

The limestone belt, in which the Knoxville ore bodies occur, has an easterly and westerly trend, is about 1680 feet wide, and rests on granite on the north, the plane of contact being nearly vertical.

It is overlain by quartzite, the contact-plane having a dip of 82°. Some mining has been done along these contacts, and a considerable amount of pay ore has been extracted, but development has been very superficial. The ore found along these contact planes contains very little manganese, and differs entirely from the ore in the limestones.

No attempt will be made to assign this limestone country-rock to a particular geological horizon, as no fossils have been found in it.

Prof. Blake, in a paper on "The Geology and Veins of Tombstone, Arizona" (*Trans.*, x., 334), speaks of the middle and upper strati-

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* Concentration and Smelting at Tombstone, Arizona. *Trans.*, xv., 601.

† Silver Milling in Arizona. *Trans.*, xi., 91.

Goodale, C.W. "The Occurrence & treatment of the Argentiferous manganese ores of Tombstone District, AZ." AIME Transactions v17 pp 767-777, 1888-89.

fied beds of limestones, shales, and quartzites as "Palæozoic and probably lower Carboniferous." There are no positive evidences of stratification in the Knoxville limestone, although indications may be noted in some places which would lead to the conclusion that the strata are parallel to the plane of contact with the quartzite.

In cross-cutting a great variation in the character of the limestone is observed. Some zones are so siliceous as to approach quartzite, though the greater part of the rock is limestone, carrying 94½ per cent. of carbonate of lime.

The ore-chimneys, which dip to the east at an angle of 40° to 50°, occur along a crack or plane of cleavage nearly vertical, and having an easterly and westerly strike. Marked evidences of slips and faults are entirely wanting, and an effort to apply the theory of hot springs to account for the origin of the ore-bodies is met with the difficulty of explaining how a sufficient opening was made for the hot water to obtain access and cut out the large channels. The chimneys are somewhat irregular in shape and vary in size. Four of them, all more or less connected near the surface, have been developed—three to a vertical depth of 400 feet, and the fourth to 150 feet.

In drifting from the main shaft, the crack or plane of cleavage above mentioned was a sure guide to the ore-bodies, though its width was not appreciable, and there was not even a knife-blade seam of "clay" or "talc" between the walls.

There were no indications of ore until the drifts were within a few feet of the ore-bodies, where the walls of the crack were stained with black oxides of manganese and some carbonate. Small detached pockets of pure manganese oxide also indicated proximity to the chimneys, but these small bodies carried very little silver. The filling of the chimneys included, in a great variety of forms, pyrolusite, wad, and psilomelane. It is not improbable that a searching examination would have discovered the rarer oxides, braunite, manganite, and hausmannite. The gangue was quartz and calcite. Galenite, cerussite, pyromorphite, cuprite, melaconite, and malachite were occasionally observed, and the assay showed a little gold—about $\frac{1}{100}$ of an ounce, or 20 cents to the ton.

Caverns were found in the widest parts of the ore-bodies which were lined with snow-white and crystalline calcite. The purest manganese ore formed the lining of the chimneys, the percentage of gangue being greater in the middle. Two classes were therefore made of the ore in preparing it for shipment, the first class being composed of the more siliceous and higher grade ore, and the second, being low in silica, was valuable as a flux, though some of it did not carry enough silver to pay for smelting.

The following analyses will show the character of the two classes of ore, which will be designated as "milling" and "smelting" ore:

Milling Ore.

Analysts: D. Baker, A. H. Low, M. W. Iles.

	Per cent.	Per cent.	Per cent.
Mn_2O_3,	74.16	42.77	41.30
SiO_2,	18.10	25.28	24.25
CaO,	1.32	21.60	18.75
CO_2,	1.33		
Fe_2O_3,	.58	3.54	6.80
MgO,	.13		
Na and K,	1.22		
Sb,	.66		
PbO,	.50		
CuO,	.20		
Ag,	.15		
Cl,	.17		
S,	.08		
H_2O,	1.67		
	100.27		

Smelting Ore.

Analyst: Walter Bunce.

	Per cent.
Mn,	47.70
O in combination,	26.22
SiO_2,	8.70
Fe_2O_3,	1.20
$CaCO_3$,	6.30
Cu,	1.21
Pb,	.45
Ag,	.06
H_2O,	6.00

The analyses of Messrs. Low and Iles were made from samples of mill-runs taken out within 100 feet of the surface. It will be observed that the percentages of Fe_2O_3 and $CaCO_3$ are much higher in their analyses than in the results obtained by Messrs. Baker and Bunce on ore taken out from a depth of nearly 350 feet.

All of the chimneys yielded ore assaying from 30 to 50 ounces silver per ton near the surface; but below 150 feet the silver contents decreased as depth was gained, with the exception of No. 2 chimney (numbering from the left), which produced a uniform quality of ore so far as it was worked. It is therefore probable that the silver was brought up in solution through the main chimney (No. 2) and that the other chimneys received their silver by overflow from it.

It is probable that the chimneys were cut out by carbonic acid waters, for the walls show unmistakable signs of corrosive action; just the effect which would be seen on a piece of siliceous limestone after treating it with acids.

The origin of the manganese is worthy of study. Prof. W. P. Blake, after a hasty visit to the Knoxville, expressed the belief that the manganese had been segregated from the limestone, through which it had been originally disseminated as carbonate. After making an analysis of some pink-stained limestone near one of the chimneys, and finding much less manganese than he expected, he wrote: "This leaves the origin of the abundant black oxides more in doubt, but I still believe that the limestone is the source." A determination of manganese in a piece of limestone taken from the 340-foot level, about midway between chimneys 2 and 3, showed 0.1 per cent. manganese.

There is hardly sufficient evidence to justify the belief that the manganese was originally formed in the chimneys as carbonate and silicate. If, on following these chimneys down below water-level—perhaps 300 feet deeper—the fillings were found to be rhodochrosite and rhodonite below all decomposing influences, all doubts as to the first form of deposition would be settled. It would be much easier to account for the origin of these highly oxidized ores if they were found in bedded deposits, for then the theories which apply to the deposition of hematites and limonites might explain their origin.

The treatment of these argentiferous manganese ores, with no smelting works in the district and no market for them nearer than Colorado or San Francisco, was the problem to be solved in Tombstone in the fall of 1881.

Efforts were first made to work them by free milling, the heaviest manganese being sorted out before shipment to the mill. This method was soon abandoned, as the silver saved did not average 60 per cent., and the loss of quicksilver was excessive—not less than 7 pounds to the ton of ore. Owing to the presence of so much manganese, this loss of quicksilver was to be expected; but it is not known whether the low yield can be accounted for by the failure to amalgamate or by the "flouring" of the amalgam with the quicksilver. Applying the test by hyposulphite of sodium to determine the amount of silver in the condition of chloride, it was found that only 24 per cent. of the silver was soluble in the hyposulphite. But this test, when tried on the best free-milling ores of Tombstone district, gave no indication of the yield to be expected by amalgamation. Such ores as the Vizina, Ingersoll, and Bradshaw yielded from 80 to 90 per cent. of their silver by free milling, but the hyposulphite chlorination test showed that from 45 to 84 per cent. of their silver was in the form of chloride.

A sample lot of the Knoxville ore was sent to the Massachusetts Institute of Technology for examination, and from tests and analyses made there, it was believed that the silver not combined with chloride was united with copper, antimony and sulphur in tetrahedrite. It will be seen from the analyses already given that no tellurium was reported, though it is not improbable that this element was present combined with silver and gold. In Prof. Church's paper (*Trans.*, xv., 602), the presence of tellurium is mentioned in the ores mined by the Tombstone Mining and Milling Company and it was found in other mines of the district.

Before giving up the hope that some of these manganese ores could be treated by the free-milling process, every chemical known in the business was tried, and in varying quantities, but it seemed impossible to prevent the manganese from fouling the quicksilver and causing a great loss. The bullion product was nearly pure silver, and so strong was the oxidizing power of the manganese oxides that the bullion showed no trace of copper even when, as an experiment, a pan-charge was run with one hundred pounds of bluestone.

After some experimental work in chloridizing-roasting in a small reverberatory furnace, under the direction of Mr. John H. Collier, which proved that the ore could be chloridized and amalgamated up to 86 per cent., the Boston and Arizona Smelting and Reduction Coompany added a White and Howell furnace and revolving dryer to their 20-stamp mill-plant, arranged 15 stamps for dry crushing, and began the treatment of the higher grade of Knoxville ores by this process. It was found by experiments with higher and lower percentages of salt that the amount required for the proper chloridization of the silver was 6 per cent. of the weight of the ore. Ore and salt were shoveled into the rock-breaker together. Dropping into the dryer, and from the dryer into the self-feeders, it was ready for the stamps. The batteries were provided with 40-mesh screens, it having been found that with a coarser screen the furnace could not do effective work. This showed that the silver was very intimately associated with the manganese. From the batteries the pulp was taken by the ordinary elevator and screw-conveyor system to the Howell furnace, which was 24 feet long and 4 feet in diameter. The cylinder was lined with fire-brick, and, acting on the idea that it was important to keep the ore from falling through the flame as much as possible, half of the bricks were placed edgeways. A short run, however, showed that the draft carried too much of the pulp into the dust-chamber, and the bricks on edge were chipped out. A marked improvement was the result, but after making another short run, a diaphragm or flange was placed on the upper end of the cylinder, which left the opening only 3 feet in diameter, and caused a still further reduction in the amount of pulp passing into the dust-chambers. This ore in the dust-chambers or flues would not have given much trouble if the auxiliary fire had been effective in completing the chloridizing action which was begun in the cylinder, but with this ore showing a chloridization of only 30 per cent., the auxiliary fire was given up as useless. There is no doubt that this dust could have been treated to the best advantage by taking it, by means of an elevator and screw-conveyor, to the lower end of the furnace and dropping it into the chamber which received the hot ore from the cylinder. But in order to carry out this plan so that the stream of ore would be regular and the action automatic, an entire reconstruction of the furnace would have been necessary. A different plan was therefore adopted. The dust-chambers were cleaned out every day, and the furnace-men fed the dust into an elevator, which raised it up to the main screw-conveyor carrying the ore from the batteries to the furnace. It may be surprising that it should stay in the furnace any better the second time it was put in than it did at first. The fact that it did so may be accounted for on the theory that the flue-dust possessed different characteristics, having been subjected to the heat of the dust-chambers long enough to lose its carbonic acid, oxygen, and moisture not expelled in the dryer.

These changes led to an increase in the chloridization from 85 up to 90 per cent. The tailings contained about 17 per cent. of the pulp-assay, which would leave 83 per cent. in bullion, but the bullion product was 81½ per cent. This difference is accounted for by the loss in dust, some of which collected on the roof of the waste-building. It assayed about 70 ounces per ton, when the pulp-assay was about 50 ounces.

An examination of the quicksilver in the pan-charges showed a somewhat broken condition, but it was no longer foul, as in the case of raw amalgamation, and there was little difficulty in collecting it in the settlers. However, it seemed impossible to avoid a considerable loss of quicksilver—about three pounds and a half to the ton of ore.

The experience of mill-men, and the theory of the reactions in a chloridizing-roast, demanded the addition of sulphur in some form to an ore like this which contained less than 0.1 per cent. of that element. (See *Roasting of Gold- and Silver-Ores*, by G. Küstel, pages 22 and 27.) But the result showed that the decomposition of the salt was vigorous enough, and that chlorination of the silver was effected without the presence of sulphuric acid. It might have been possible to get a higher chlorination of the silver if the theory of Küstel—that "calcareous ore requires as much more green vitriol or iron pyrites as is necessary to transform all the lime into sulphate"—had been put into practice; but sulphuretted ores in sufficient quantity were not available, and the use of copperas was out of the question, as will be seen by the following figures: The analyses of Knoxville ore show from 2.65 to 21.60 per cent. of $CaCO_3$. These were probably extremes, and the average was not far from 10 per cent. This would give 5.6 per cent of CaO, or 112 pounds to the ton, and in order to convert this into CaO, SO_3, 160 pounds of SO_3 would be required, or more than 500 pounds of copperas ($FeSO_4 + 7H_2O$).

It is evident that this method of introducing sulphuric acid would not do on 50-ounce ore, when the cost of copperas laid down in car-load lots exceeded 4 cents per pound.

It is worthy of note that the ore as it dropped from the cylinder into the chamber was at a very low red heat, and imperfectly chloridized (not over 60 per cent. of the silver being combined with chlorine), but that while accumulating in the hot chamber the reactions went on with vigor.

The total production of the Knoxville mine to date has been 6000 tons of "milling" ore, averaging 43 ounces per ton, and 6200 tons of "smelting" ore, assaying 23.3 ounces per ton.

Nearly all of the smelting-ore was worked by the Tombstone Mining and Milling Company in smelting concentrates, and Prof. Church has mentioned the treatment of this ore in his paper already referred to on "Concentrating and Smelting at Tombstone."

If the Tombstone district had produced lead-ores so that the "milling" ores could have been worked by smelting, the profits of the mine would have been greatly increased. Milling was too expensive with salt at $30 per ton, boiler-wood at $9, and pine wood for roasting at $12 per cord (making the cost per ton of ore for steam fuel $3.50, and for roasting $2).

I am indebted to Mr. Frank C. Earle for the following analyses of the limestones of the Tombstone district:

	$CaCO_3$.	$MgCO_3$.	SiO_2.
No. 1,	91.33 per cent.	trace	6.00 per cent.
No. 2,	90.75 "	2.85 per cent.	5.20 "
No. 3,	96.46 "	trace	2.41 "

No. 1. Main working shaft, "Lucky Cuss," near contact with granite. White and crystalline.

No. 2. West end of "Knoxville." Blue and compact.

No. 3. "Luck Sure." Represents general character of limestone in the belt.

What little Fe, Al and Mn occurred in the samples was not determined.

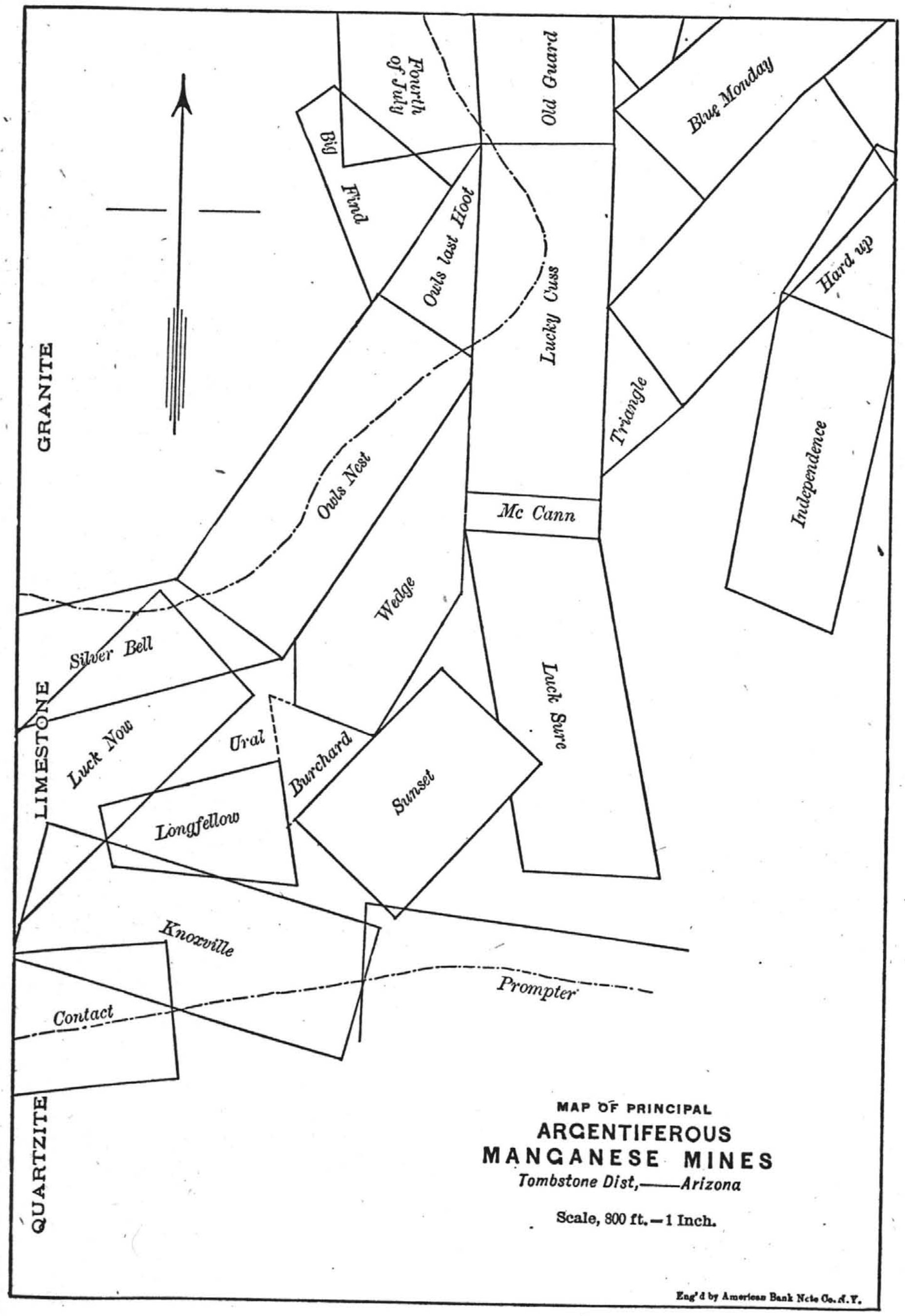
I am also indebted to Mr. H. G. Howe, M.E., for the accompanying map, showing the location of the group of mines referred to. The dotted lines indicate the granite-limestone and limestone-quartzite contacts as traced on the ground.

In the eastern part of Tombstone district there is another belt of limestone, in which are located the Bunker Hill, Rattlesnake, and Mammoth claims; the ores from these claims contain much manganese, though not to the same extent as the Knoxville, Lucky Cuss, and Wedge ores.

Discussion.

Richard Pearce, Argo, Colo. (Communication to the Secretary): I do not quite see the necessity for the "channel-theory" to account for the formation of these deposits. The gradual substitution of one mineral by another, through the agency of water and carbonic acid, would be sufficient, in my judgment, to account for them.

In connection with the remarks of Mr. Goodale as to the original form of the manganese minerals in these ore-bodies, I may observe that somewhat similar conditions exist at Butte, Montana, where large deposits of psilomelane and pyrolusite are found in comparatively isolated positions in the country-rock and are evidently the result of water-action. Carbonate of manganese enters largely into the composition of the veins adjoining these isolated deposits, and



MAP OF PRINCIPAL
ARGENTIFEROUS
MANGANESE MINES
Tombstone Dist,——Arizona
Scale, 800 ft.—1 Inch.

water circulating through the veins, containing, perhaps, manganese carbonate in solution in carbonic acid, finds some lateral outlet through the natural joints of the rock, and by a process of gradual displacement these manganese oxides are formed.

Similar conditions also exist in regard to the silver contents of these Butte deposits. I think that, as a rule, the richer the ore in manganese, the poorer in silver; this would indicate that possibly silica may play some important part in the transfer of the silver from one point to another.

Mr. Goodale's account of mill-experiments confirms my impression that the action of MnO_2 on quicksilver in the amalgamation of silver-ores is scarcely understood. It appears from all the evidence we can obtain, that under certain conditions MnO_2 is capable of giving up its oxygen in some nascent form which acts most energetically on the quicksilver. This action is, in all probability, oxidizing, as the flouring of the quicksilver may generally be avoided by the addition of some baser metal, such as lead or copper, these metals being more readily oxidized than mercury. In the treatment of silver-ores, containing much base metal, by amalgamation, it is often found desirable to add manganese oxide, which has the effect of preventing the reduction and amalgamation of the base metals and leads to the production of a much finer quality of bullion.

Mr. Goodale speaks of the supposed necessity of adding sulphur to effect a chloridizing roasting. This my own practice leads me to think an error. I worked the Augustin process for many years on copper in a perfectly oxidized form, containing silver, without the aid of sulphur in any form. When the oxide of copper was brought to a proper temperature in the furnace, the chloridizing was effected by the addition of a mixture of fine siliceous sand and salt, moistened with water. The following is probably the reaction:

$$2NaCl + SiO_2 + H_2O = Na_2O, SiO_2 + 2HCl.$$

J. K. CLARK, Butte City, Montana: I can add very little of interest to what has already been said about manganese-ores in milling; but it may be a point worth noting that it has been our experience at the Moulton mill that wherever a large amount of zinc has been present in our ores, the loss of silver by volatilization has been much reduced by a plentiful mixture of oxidized manganese ore.

Another point may be mentioned as showing the important action of iron in assisting amalgamation. While running the Dexter mill in Butte, in 1876, where we chloridized in reverberatory furnaces, the tailings continued to rise in value most unaccountably, until the saving was less than 60 per cent., though the chlorination tests showed 95 and 96 per cent. of the silver in the form of chloride and proved that there was no fault in the furnace-work. This happened while we were expecting new mullers, and as soon as they arrived and were put in, the yield went right back to where it should be, according to the chlorination-tests.

An examination of the old mullers and other iron parts of the pan showed that they were so heavily coated with iron oxide, say $\frac{1}{16}$-inch thick, that no metallic iron could come in contact with the pan-charge. Since that time, I have taken good care that there is no lack of bright clean iron in the pans, and I believe the plan we have adopted at the Moulton—placing two or three wrought-iron bands, $\frac{1}{4}'' \times 4''$, around the inside of the pan—will always assure enough live iron to assist the amalgamation.

It is generally believed that the poor results obtained in a pan-charge of slimes alone are due to the thinness of the pulp, and the fact that the quicksilver cannot be well mixed with it and come in contact with the silver; but it is my opinion that the coating of the iron parts of the pan by the slimes, which would prevent the activity of the iron, may offer a better explanation of such results. When slimes and sand are worked together, the scouring action of the sand gives the iron a chance to play its part.

MR. GOODALE: In connection with the remarks of Mr. Pearce about the oxidizing action of MnO_2 on quicksilver, I would say that the Boston and Arizona Company purchased all the base and sulphuretted ores they could get, and offered good prices for such ores to mix with the Knoxville ore. It was found that whenever a mixture could be made which would yield a bullion-product containing from 5 to 10 per cent. of base metal, the saving was increased and the quicksilver was in better condition.

M. EISSLER (1901)

THE

METALLURGY OF SILVER

A PRACTICAL TREATISE

On the Amalgamation, Roasting, and Lixiviation of Silver Ores

INCLUDING THE ASSAYING, MELTING, AND REFINING OF SILVER BULLION

BY

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Capio Lumen

LONDON
CROSBY LOCKWOOD AND SON
7, STATIONERS' HALL COURT, LUDGATE HILL
1901

D. VAN NOSTRAND COMPANY,
NEW YORK.

the surface of the table lightly, aiding the even distribution of the material and exposing the particles more thoroughly to the action of the water. The blankets are taken up from time to time and washed out in a tub of water, usually once in twelve hours. While the blankets of one table are being washed, the stream is turned so as to run over the neighbouring tables. The concentrations washed from the blankets are collected and worked in pans. They usually yield from £3 10s. or £4 to £6 per ton.

The profit accruing from this source to the mill reduces considerably the original cost of crushing and amalgamating.

Various other contrivances for concentration have also been introduced.

Tailing Reservoirs.—The tailings coming down the cañons from the mills above, after having passed over the blanket-tables, or having been subjected to other methods of concentration, are finally allowed to accumulate in reservoirs. Some of these, of small capacity, are placed along the course of the streams, but the principal deposits of that sort are on the level land adjacent to the mouths of the cañons. Thus at Dayton, where Gold Hill Cañon opens upon the plain, there are two or three reservoirs, the aggregate contents of which probably amount, at present, to 400,000 tons. This quantity is daily increased by what is brought down from the mills above. Further down the river, near the mouth of Six Mile Cañon, and receiving everything brought down from the mills on that watercourse, is another known as the Carson reservoir, containing not less than 200,000 tons of tailings. In Six Mile Cañon, two miles above its mouth, is a smaller reservoir, formerly estimated to contain 100,000 tons, but of which a large portion was swept away some years ago by freshets. The quality of the tailings in these dams varies considerably, depending on several conditions; among others, the proportion of slimes that may be mixed with the sands. Thus assays of the slimy and richer parts may show a value of £5 or £6 per ton, while the coarse sands vary in value from £1 to £2 or £3

per ton, according to the original character of the ore and the degree of efficiency with which its valuable contents have been extracted. The smaller reservoirs around Dayton are generally richer than the large ones.

Since the discovery of the Consolidated Virginia and California ore bodies on the Comstock lode—generally known as the famous Bonanza mines—immense quantities of tailings have been accumulated which are now being treated.

Successful Concentration of Slimes.—In later years considerable attention has been devoted to the question of concentrating the tailings on proper machines. This is by no means an easy question when it is considered that after the fine pulverization of the ore in the battery the same undergoes a grinding process during the pan amalgamation, lasting from three to four hours, whereby the ore is reduced into an almost impalpable powder. As for the slimes, they consist generally of the finest particles of the chlorides, and the easily friable brittle silver ores, float gold if any, and the clay or talcose portion of the ore. As the name "slime" indicates, it is a slimy, pasty agglomeration of matter, which one would hardly judge capable of bearing a mechanical separation; but it has been found that with the best of concentrators, like the Frue vanner, and properly constructed buddles, a proper concentration of tailings and slimes may be effected. They have been thus successfully dealt with at several mills, and as examples I may cite the cases which follow.

Concentration of Tailings at Tombstone, Arizona.—The ores from Tombstone mine above water-level were mostly chlorides in quartz gangue, containing also lead carbonate, manganese and iron oxides, and some sulphides of silver, iron, copper, lead, and zinc. They assayed on an average 60 oz. of silver and ⅛ oz. of gold per ton and 3 per cent. of lead. With depth the chlorides gave way to the less tractable sulphides. Tellurides of silver and gold also made their appearance. The surface ores were closely milled, averaging 85 per cent. of the silver and 45 per cent. of the gold contents. These results disappeared as the ore lost its chloride character and began to carry its silver in the form of sulphide.

Up to March, 1884, the mill had amalgamated 89,608 tons of ore, estimated to contain 4,168,527 oz. of silver and 18,244 oz. of gold, and had produced 3,225,110 oz. of silver and 9,454 oz. of gold. This would leave tailings containing about 10·5 ozs. of silver and 0·098 oz. of gold per ton, or a value of $15·60 at the legal rate for silver. The actual value at market prices at the time of the operation was about $12 per ton.

Mr. T. A. Church, the superintendent of the mine, gives the following description of the apparatus and machinery which he erected for the concentration of the tailings :—

"The amount of silver and gold locked up in tailings, which were accumulating at the rate of 15,000 to 25,000 tons a year, and were worth about $12 a ton, was so great that its recovery became a serious problem. The ore being thoroughly oxidized, no benefit could be expected from weathering, and amalgamation having failed once to extract the metals in the tailings, it was assumed that it would fail again. Roasting and chlorination were prohibitive by their cost, which was not less than $20 or £4 a ton at that time and place, or twice the value of the tailings. Guided by the fact that the lead carbonate carried a high percentage of silver, experiments were immediately made in concentration. A second amalgamation was also tried and yielded about $1·50 per ton.

"At that day, 1883 to 1884, the experience had in concentrating pan tailings was not at all reassuring. Experiments had been made, but without success, except on ore that contained as much as 8 or 10 per cent. of lead. Ores of 3 per cent. lead, like those in Tombstone, had not been successfully treated. The outlook for utilisation of the concentrates was also poor. No iron ore for flux was at hand, and the only substance that was free from silica was limestone. There were on the company's property some mines of manganese ore, carrying about 20 oz. of silver to the ton. This ore would not amalgamate

well, and trials made subsequently proved that it would not concentrate well.

"Under these circumstances it was determined to undertake concentration of the tailings on a large scale, and if this succeeded to attempt to smelt the concentrates in a shaft furnace with manganese as the flux.

"Experiment showed that the tailings could be concentrated either on the Frue vanner or on the German rotating round table. The principal difficulties experienced were from the extreme fineness of the tailings, which had been stamped through screens of 30 and 40 mesh, giving pulp of $\frac{1}{40}$ to $\frac{1}{60}$ in. diameter as a maximum, and from this down to the finest particle. The proportion of very fine slime was increased greatly by grinding in the pans, so that probably 60 per cent. of the ore was in the condition of slimes sufficiently fine to form a tenacious mass, though no more than 3 or 4 per cent. of clay was present. In the course of the work two mills were built.

"*First Concentrating Mill.*—The mill first built contained six Frue vanners and three round tables, the latter serving entirely as tailing machines to the vanners. An ordinary agitator, such as is found in pan mills, 9 ft. in diameter, served to receive the dry tailings taken from the old beds and mix them with water. This mixer was connected with a mill of 15 stamps, the tailings from which ran directly to the mixer. The three discharge-plugs, usual to settlers, were retained, but were bored with 1-in. holes, limiting the discharge, so that the pulp was kept at a certain height in the mixer. With about nine revolutions per minute of the mixer arms, the current was not sufficient to carry off the heaviest part of the pulp. This settled to the bottom of the mixer, and was shovelled out periodically. It was rich enough in lead for smelting, and was richer than any other part of the product in gold and silver.

"The rest of the tailings ran from the mixer to the six Frue vanners, on which it was distributed without sizing. The tailings from the vanners were collected in a ~~belt~~ elevator, and raised high enough to run on the round tables.

"The vanners worked well when the quantity passed over them was restricted, but when it reached 5 tons a day the fine part of the slimes was carried over and lost. On this account the saving of lead in this mill was much less perfect than afterwards when facilities for handling larger quantities were obtained. This mill ran for about a year and a half. The work done in the first thirteen months is shown by the following table:—

THIRTEEN MONTHS' WORK AT FIRST MILL.

	Tons.	Assay per Ton.			Per Cent.
		Silver.	Gold.	Lead.	
		oz.	oz.	per cent.	
Mill-tailings treated . .	11,467	13·21	0·22	8·00	
Production:—					
From the mixer . .	93	52·65	0·48	23·20	
,, ,, Frue vanners .	1,483	45·22	9·58*	30·90	
Percentage saved by weight .					13·31

Weight of tailings required to make one ton of concentrates, 7·5 tons.
Percentage saved, by value: Silver, 41·29; Gold, 34·09; Lead, 50·61.

"Although the tailings treated in this mill were estimated to contain 8 per cent. of lead, it was known that the old beds as a whole would not contain more than 3 per cent., the stock for this mill being taken from the best and richest parts of the beds.

"*Second Concentrating Mill.*—The attempt thus made to concentrate was not considered an entire success until the round tables were put in. They were introduced to prevent the loss of fine material which passed over the vanners, and they proved to be so well adapted to the treatment of the finest slimes that a new mill was designed in which they bore all the work of concentrating the slimes, while jigs were made to treat the coarse product that had settled in the mixer. In addition to the changes, sizing was introduced, both by trommel screens and by hoppers with a rising current of water. The old mixer was replaced by an agitator made like a pug mill. It consisted

* This is probably erroneous, as 7½ tons of tailings, worth 0·22 oz. gold, could not produce 9·58 oz. in the concentrations.—M. E.

of an upright box, 30 in. square, with the corners filled in to make an octagon. A shaft making 105 revolutions per minute stands in the centre, and carries a frame or basket of ¾-in. iron bars, which rotates just within a number of rods that project inward from the sides of the agitator. The construction of this machine gave more trouble than any other part of the mill on account of breakages. At first the central shaft carried radial arms that ran between the fixed arms of the box; but when the latter were cut off and the former reduced to a basket of vertical arms running past the ends of the fixed rods, the machine ran for months without a stoppage.

"This mill was designed to use dry tailings from the old beds, and also the current product of tailings from a mill of 20 stamps, treating from 40 to 60 tons a day. The mill tailings were drawn from the settlers, each of which contained two pan charges, or about 2¾ to 3 tons of ore with about 1,200 gallons of water. The discharge of a settler took place in about five minutes, and to prevent a rush upon the concentrating machines the mill tailings were received in a box, about 16 ft. long and 2 × 2 ft. section, with three discharge openings at one end. When a settler was discharged this box would fill, and the heavy tailings settled to the bottom. As soon as the flush was over the surplus water would run out, and the deposit in the bottom of the box was removed gradually by a stream of clear water which poured with some force from a spout. All of the water needed for mixing with the dry tailings passed in this way through the equalizer.

"The equalizing box, as this contrivance was called, discharged into the agitator or mixer, which was fed with dry tailings by hand.

"The dry tailings were wheeled from the old settling pits to a platform, and then shovelled with regularity into the agitator. Shovelling stopped when the mill was sending down tailings, and was resumed when the flush began to decline. From the agitator the tailings, now become pulp, ran to a belt elevator with 12-in. buckets, lifting 26 ft. high, and entered the mill at one corner of the building. From this point they ran through two trommel-screens to a series of six hoppers, forming the sizing apparatus and occupying the upper story of the mill. The last two of these hoppers were quite capacious, holding probably 600 gallons. They would fill to the brim during a flush, but in the intervening period the water level in them would sink so low that the discharge launder of the fifth hopper was not covered, and the sixth received no pulp. During a flush the water-level would rise in the hoppers, and their spouts discharged an increased quantity of pulp, that showed its effects immediately in a thicker deposit on all the concentrating machines. Thus the effects of flushing the tailings down from the mill were met partly by stopping the use of dry tailings, partly by storage in tanks and hoppers, and partly by greater supply of pulp to the concentrating machines, and it was constantly shown that all of these resources were needed to reduce the fluctuations due to this cause to their lowest possible value as disturbing factors.

"The trommels had punched screens of $\frac{3}{64}$-in. mesh, wire screens being used also, but giving trouble from the opening of the meshes. The trommel rosettes had round wrought-iron spokes, and a 1-in. blank nut was strung on each spoke to give percussive action. Both trommels sent their through-fall to the line of hoppers and their coarse stuff to the first jig. The second jig was supplied from the first hopper, and the second, third, and fourth hoppers supplied three round tables, while the fifth and sixth hoppers supplied three other round tables. The jigs had percussive action, the pistons being carried by springs, and forced down by the blows of a ram. The speed, 120 strokes per minute, was not enough for such fine material.

"The round tables were all 15 ft. in diameter, turning 105 times in one hundred minutes, and had a slope that varied from 7 in. in $7\frac{1}{2}$ ft. for coarse slimes, to $4\frac{1}{2}$ in. for fine slimes. All of them were covered with Akron cement, which is well adapted to this use. Brushes were not used, the ore being cleaned and the concentrates washed off by jets of water. These machines did excellent work. The cement surface, combined with the thinning of the stream of pulp as it spread from the centre to

the circumference, caused the retention of the fine carbonate of lead and other heavy minerals most perfectly. It was proved that when the concentrates were once deposited, the losses by cleaning were very small, most of the loss occurring in the very fine slime that ran over the table on the raw pulp. The mill was overcrowded, and with slower work it is quite certain that much better results could be obtained, even upon pan tailings. Two jigs and six tables were expected to treat 120 tons a day, but they frequently treated 150 to 170 tons at a time when the tailings were so fine that the jigs did not do their proper share of the work. Some of the tables treated a ton an hour constantly.

"In considering the following table it is to be remembered also that the choicest part of the tailing beds had been removed before the second mill was built.

ONE YEAR'S WORK AT THE TWO MILLS, April 1st, 1883, to March 31st, 1884.

	Old Mill.	New Mill.	Total.
Days run	126	144	270
Tons treated	3,346	13,623	16,969
New tailings		6,150	6,150
Old tailings	3,346	7,317	10,663
Ore crushed		156	156
Product, tons	395·20	1,495	1,890·20
Ratio, tailings to product			1 : 8·9

Per cent. saved by concentrates	Gold	48·81
	Silver	40·57
	Lead	72·06
Do. by tailings	Gold	55·53
	Silver	53·11
	Lead	77·61

"The actual saving was greater than the table shows. The tailings from the tables on which the finest slimes were treated were run through a series of six settling tanks, and a product containing about 8 to 10 per cent. of lead and 12 to 15 oz. of silver obtained. This was used as a binding substance in making the concentrates into bricks, but no account was taken of this material in estimating the work of the mill.

"There were two constructive defects in the mill. The sorting hoppers proved to be very inefficient. It was not necessary to sort the stock closely, but it was very important to separate the finest slime from coarser sizes; and this the hopper failed to do. Every one of the concentrating machines that depended on the hoppers received a considerable proportion of slime; and it is likely that much of the richest and heaviest part of this slime followed the coarse table stock to those tables which had the greatest slope and were least suited to its treatment. The hopper shape seems to be the worst that can be utilized for the action of a rising stream. Many experiments were made to ascertain the source of the losses, and always with the result of locating them mostly in fine slime contained in the pulp after it had run over a table, that is to say in material that never rested on the table surface. When once deposited, the heavier portion of the pulp could be washed clean with very little loss.

"The other defect was remedied easily enough. The coarser grains of the tailings were rounded, and were apt to run over the table surface without stopping. The Frue vanners were replaced to work up this part of the stock, and their percussive action proved to be useful.

"It is impossible to say how far the losses could have been obviated by a more perfect system of sorting. Very much could have been done, but it is not probable that the losses would have been reduced below 25 per cent. except by crushing the coarse part of the tailings so as to unlock the minute particles of silver minerals enclosed in them. Probably one half the loss was due to this cause and one half to slimes.

"It was proved conclusively that concentrating machines can deal successfully with the finest slimes. A seventh round table was built for the purpose of reducing the silica in the extremely fine slimes, that were used for binding materials in making the concentrates into bricks for the subsequent smelting operation in the shaft furnace. This material was finer than flour, and was about like the dust that rises on a light wind. Even the heavy concentrates could be blown away by a light breath, though no trouble was experienced in saving them.

"The cost of the work varied with the constantly increasing distance of the tailing beds from the mill. The first mill was run by water power, and used a large proportion of tailings direct from the amalgamation, and under these circumstances the cost was about 92 cents per ton. When the tailings were brought in by hand, water power being retained, the cost rose to \$1·39, both of these data relating to Frue vanners. When the tables were put in and a larger quantity of material handled and the treatment of tailings direct from amalgamation was resumed the cost was \$1·23, though steam power was used exclusively, and increased the cost 24 cents a ton. These figures of cost cover the experimental stage of both mills, and should be reduced materially for regular and experienced work.

"The quality of the concentrates was excellent. They contained more than 50 per cent. lead, and an amount of silver that varied according to the material from which they were made."

Concentrating Tailings at the Montana Co.'s Mine.*— Here, as at Tombstone, pan tailings from one of the company's mills are carried by launders to the tailing mill, where they undergo a preliminary sizing in a series of spitzkasten, and discharge through a syphon on to the Frue vanners. Each of the spitzkasten—there are five of them—discharge each on to a separate vanner. The tailings leaving the vanners show that the work has been well performed, and that a large percentage of the mineral particles have been collected on the vanners; and what goes to the pit, although not worthless, assays very low. (The amount is not stated.) In the 50-stamp mill twenty Frue vanners are set up, so as to receive the discharge from the agitators and the pulp from the end of the vanners, or tailings flow to the tailing pit to undergo an "oxidation process," with a view to further treatment subsequently. The subjoined paragraphs are in the director's own words:—

* I am indebted to the Directors of the Montana Mining Company for the information here given. An account of the operation of the Montana Company's mills will be found later on, p. 125.