DISSEMINATED PRECIOUS METALS – TRINITY MINE, NEVADA

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1. Background
1.1 Overview of deposit types

- **Deposit types in Nevada**
  - Carlin-type deposits
    - Majority of gold production in Nevada
    - Gold occur predominantly as native metal(size less than 1μm)
    - "noseeum" gold: invisible to the naked eye
    - Spatially associated with granites and intrusion driven hydrothermal system
    - Silicification is the commonest form of alteration
  - Epithermal deposits
    - Volcanic hosted deposits
    - 3 general types: acid sulfate/ adularia sericite/ alkalic
  - Gold-rich porphyries
    - Associated with granitic intrusives
    - Gold correlates with copper grade, K alteration

Fig. 16.1 / Fig. 16.2

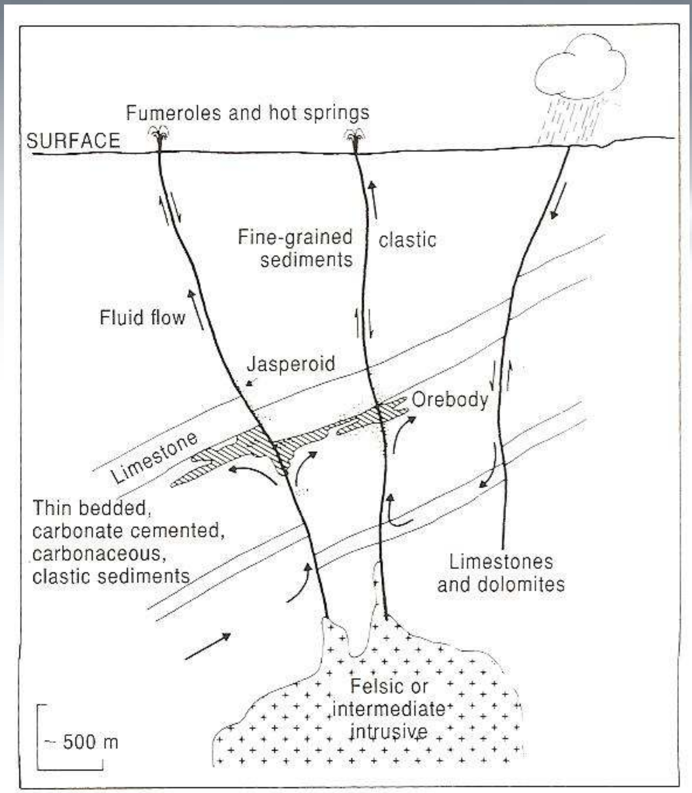

Fig. 16.1 Diagram for the formation of Carlin style deposits.

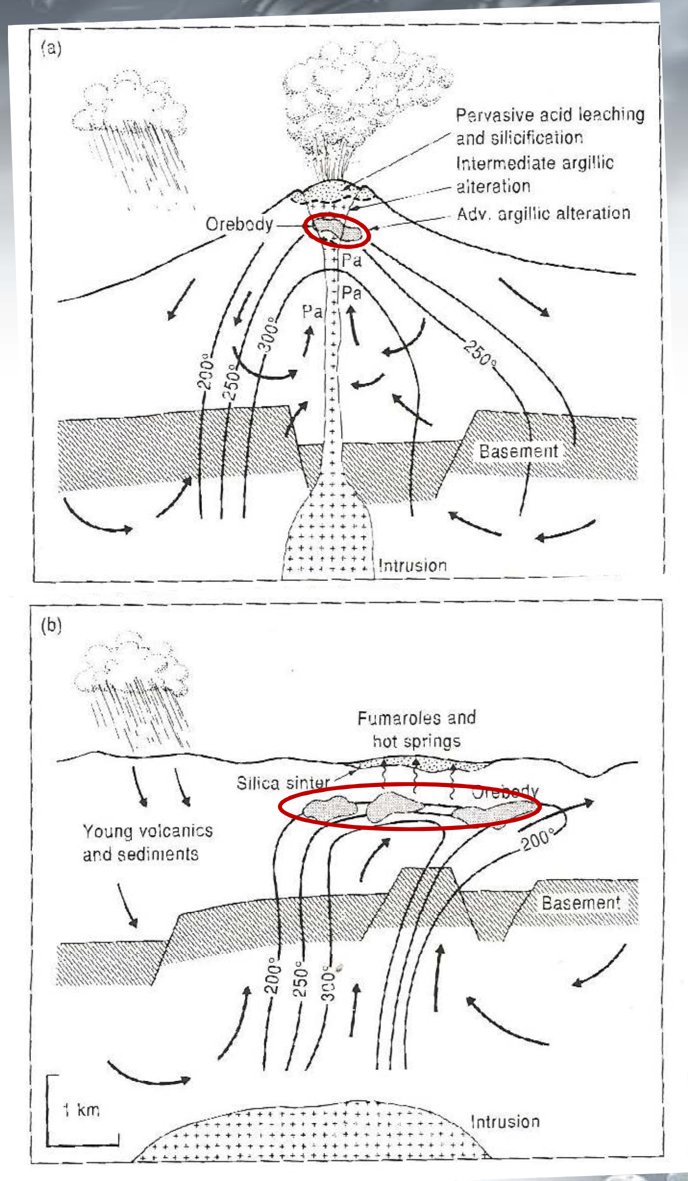

Fig. 16.2 Diagram showing the formation of two types of epithermal precious metal deposits in volcanic terranes.
(a)Acid sulfate type (b) Adularia-sericite type

1. Background
1.2 Geochemistry

- **Developments in gold geochemistry**
  - Sampling and analytical techniques devised to determine all the “noseeum” gold presents
  - AAS/ ICP-MS: detection limits of lower than 5 ppb
  - Bulk Leach Extractable Gold(BLEG) technique
    - To achieve adequate precision, it is necessary to have 20 gold grains in each ample.
    - It means taking stream sediment samples of around 10 kg.
    - Alternative strategy: take a large sample and leach it with cyanide where rocks have been oxidized
  - Pathfinder elements: As, Sb, Hg, Tl and W for sedimentary hosted deposits
  - Chip sampling of apparently mineralized rocks, particularly jasperoids, has been successful

1. Background
1.3 Geophysics

- **Disseminated gold deposits are difficult geophysical targets**
  - Electrical and EM methods: map structure and identify high grade veins
  - IP method: unoxidized sulfides
  - CSAMT survey: successful uses of geophysics in Nevada
    - Detect silicified bedrock under Tertiary cover

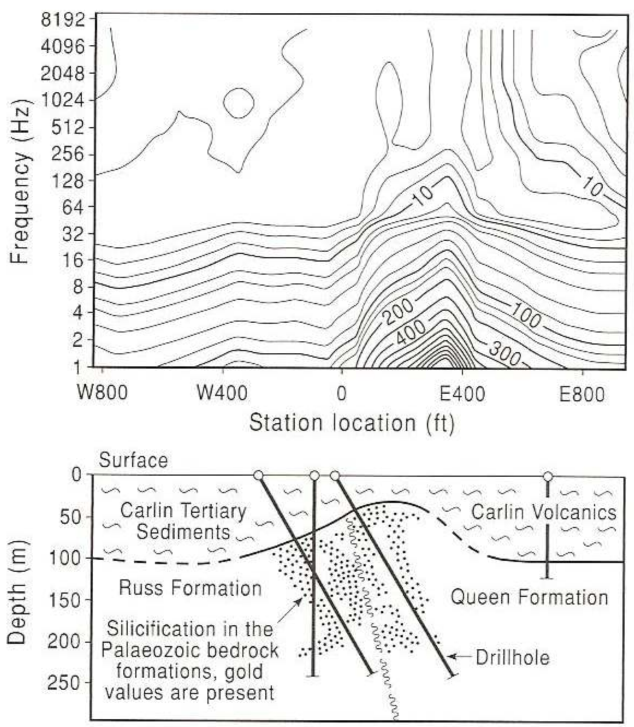

Fig. 16.3 Section showing the application of a CSAMT survey in detecting areas of silification under Tertiary cover.

Top: contoured data; bottom: drill section.

1. Background
1.4 Mining and metallurgy

- **Effective grade control**
  - Different grade ores are treated differently in most operations
  - Higher grade: milled and extracted with cyanide in a conventional manners
  - Lower grade ores: crushed and placed on leach pads

2. Trinity Mine, Nevada

- **The Trinity Silver Mine**
  - Open pit, heap leach, silver mining operation extracting rhyolite-hosted, disseminated, hydrothermal, silver oxide mineralisation.
  - Produce on September 3, 1987 and mining ceased on August 29, 1988.
  - Silver mine rather than a gold producer: by the availability of data
  - Statistical assessment of blasthole assay data for the purpose of determining the distribution and quality of mineralisation
  - Trinity Mine in Pershing county
    - Northwest flank of the Trinity Range
    - 25 km north-northwest of Lovelock
    - Elevation: 1200 m to 2100 m (mineralisation between 1615 and 1675 m)

Fig. 16.4

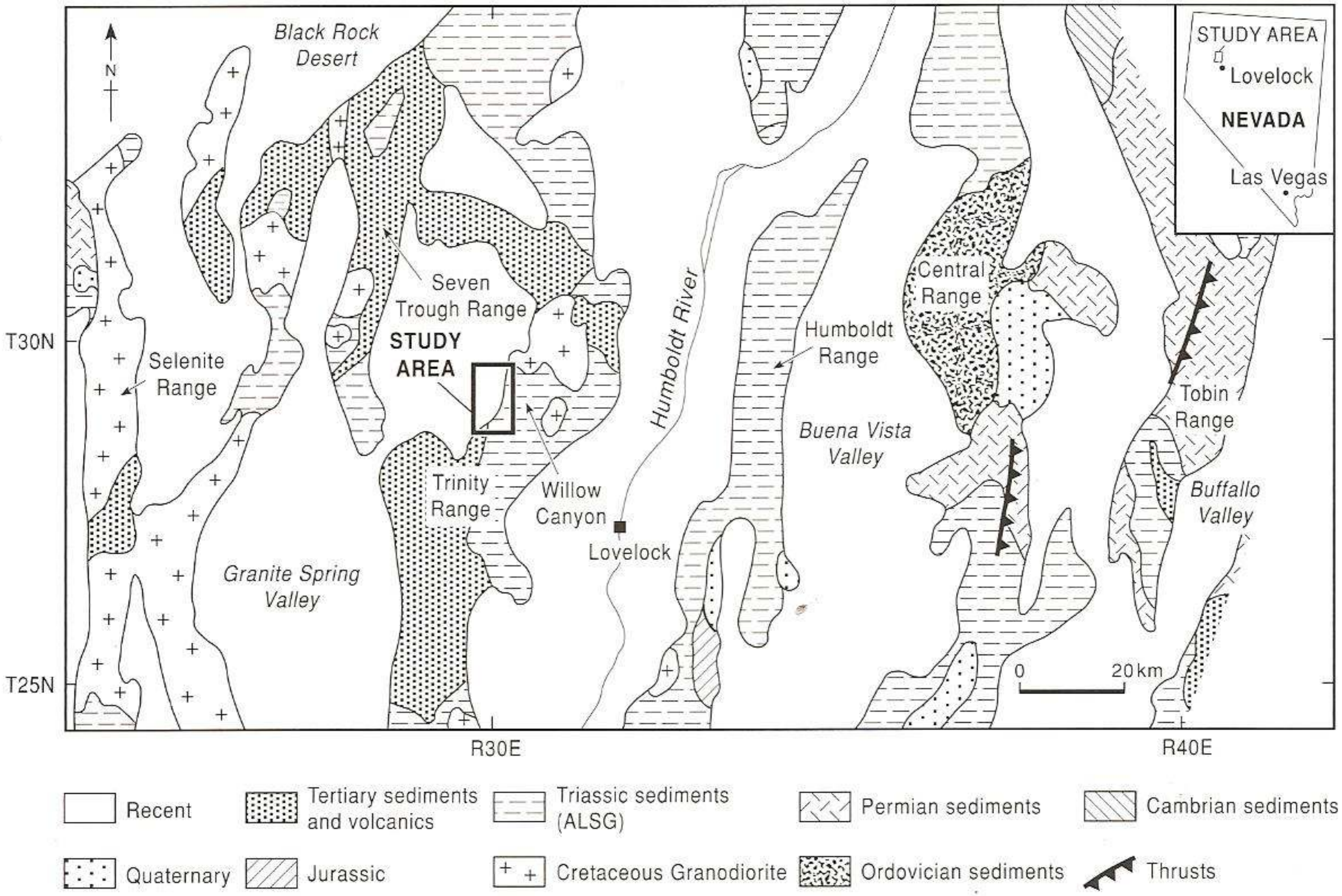

Fig. 16.4 Sketch map of Pershing County, Nevada showing the outline geology and location of the Trinity silver deposit.

Fig. 16.7

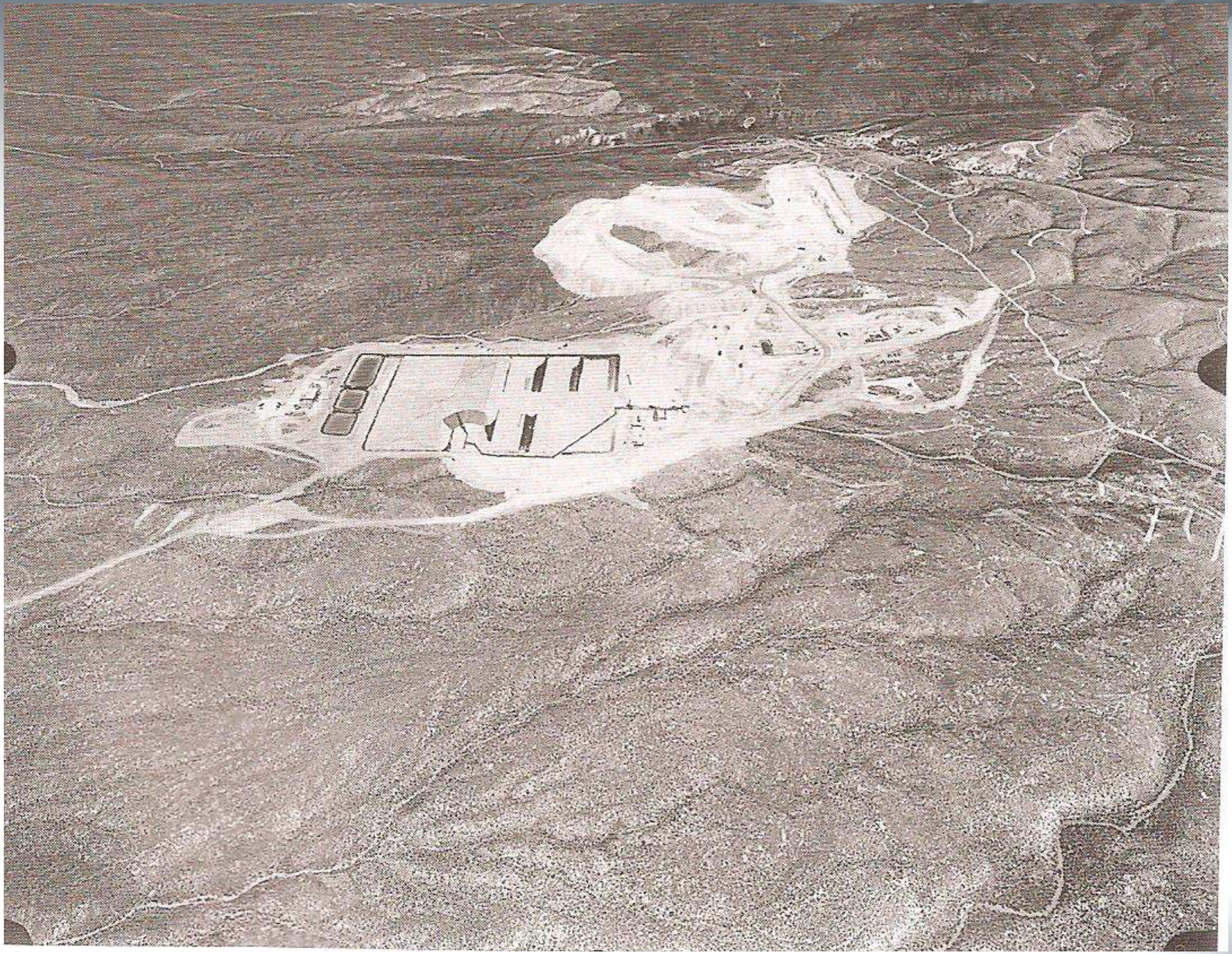

Fig. 16.7 Aerial photograph of Trinity Mine.

Trinity Silver Mine Exploration by AuEx Ventures Inc.

http://www.auexventures.com/s/TrinitySilver.asp

Looking SW along Trinity Silver Pit

Mineralized breccia matrix in rhyolites

Core rig drilling in the pit 2006

3. Exploration
3.1 Previous work

- **First discovered in the Trinity Range**
  - By G. Lovelock in 1859
- **Limited, unrecorded production**
  - Pb-Ag and Ag-Au-Cu-Zn veins between 1864 and 1942
- **Geophysical exploration and trenching**
  - By Phelps Dodge within Triassic sediments to the north of Willow Canyon during the 1960s
- **Geochemical exploration**
  - By Knox-Kaufman Inc. on behalf of US Borax
  - Significant silver show was found within altered rhyolites in 1982

3. Exploration
3.2 US Borax exploration & 3.3 Mapping

- **During 1982-1986, US Borax carried out exploration**
  - In 1982 and 1983: mapping, geochemical and geophysical techniques to locate payable sulfide mineralisation
  - In 1983: drilling within an area known to host sulfide mineralisation
  - In 1985-1986: exploration to find additional reserves
  - Sulfide zone / high grade oxidized zone

- **Mapping**
  - Initial mapping: 1:500
  - Detail mapping: 1:100 (sulfide zone) / oxidized zone in 1986
  - Mapping showed the host rock, of both oxide and sulfide mineralisation, to be fractured rhyolite porphyry and defined an area of low grade surface mineralisation intruded by barren rhyolitic dykes.

Fig. 16.5

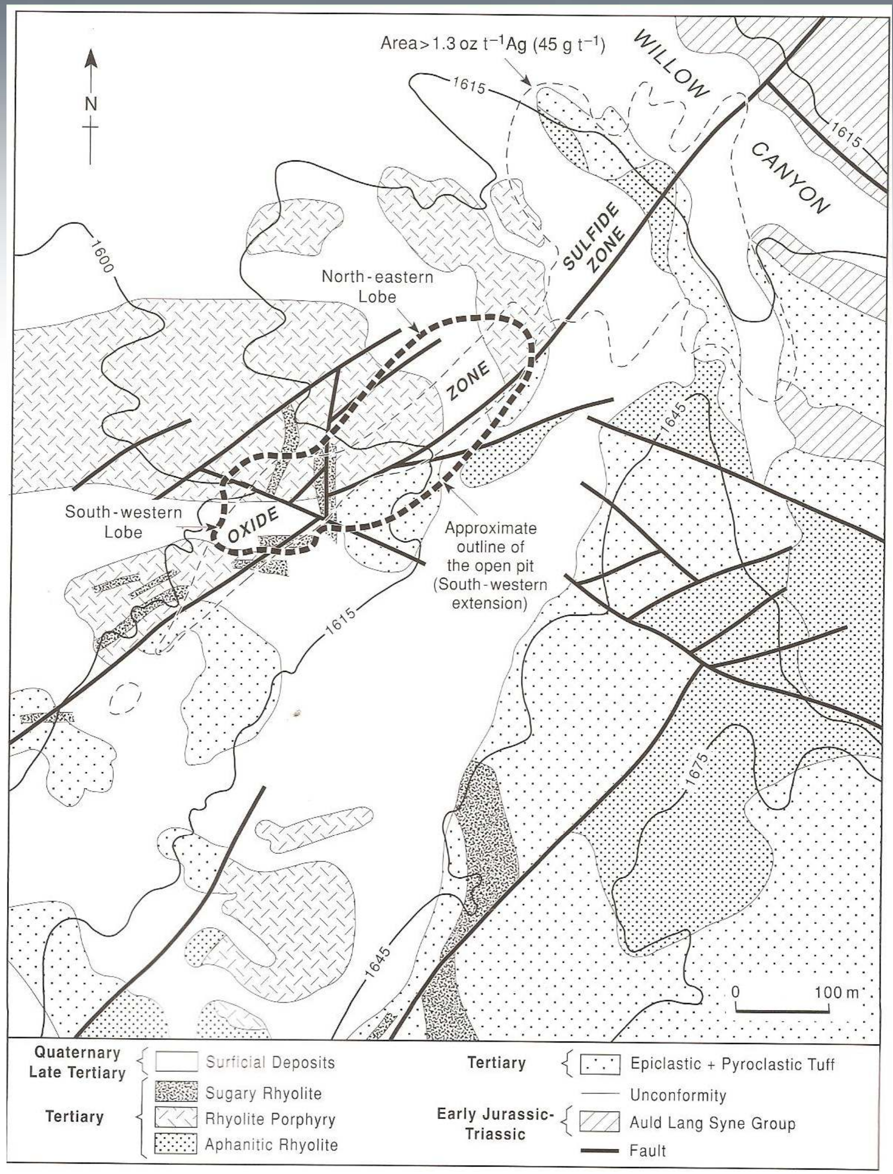

Fig. 16.5 Sketch map of the geology in the vicinity of the Trinity silver deposit, Nevada

3. Exploration
3.4 Geochemistry and geophysics

- **Geochemical survey**
  - Soil survey: sampled over the oxide and sulfide zones
    analyzed for Pb, Zn, and Ag
    - Pb used as a pathfinder element for Ag mineralisation
    - Significant Pb anomalies: over the sulfide zone(> 100 ppm)
  - Rock sampling: as part of a reconnaissance survey
    help define the extent of surface mineralisation
    - Rock chips from drilling, trenching and surface exposure analyzed for Pb, Zn, Ag, and Au
    - 40-90 ppm Ag were recorded as the zone of oxidization was traced southward along strike
  - Anomalies from the rock and soil surveys were used in the planning and layout of the drilling program within the sulfide zone
- **Geophysical survey**
  - Gradient array IP, magnetic and gamma ray spectrometry over the sulfide mineralisation
  - A time domain chargeability anomaly coincided with the area of sulfide mineralisation

3. Exploration
3.5 Drilling

- **Drilling**
  - 100 ft (33 m) grid/ total 29,880 m drilled
  - Most of drilling was focusing on the surface exposure of silver mineralisation, Pb, and IP anomalies and areas of favorable geology
  - Drilling defined a body of silver mineralisation dipping to the west
  - In 1985, drilling was concentrated within the southwest extension (oxide zone): 92 holes
  - Diamond drill hole: every 1-3 ft for metallurgical testing
    - Analyzed for Ag, Au, Pb, Zn, and As (AAS)

Table 16.1 Summary of drilling exploration programs

Drilling methods	Number of holes	Total meterage
Percussion	199	22,857 (74,990 ft)
Reverse circulation	39	6257 (20,530 ft)
Cored	10	765 (2511 ft)
Total	258	29,879 (98,031 ft)

Fig. 16.6

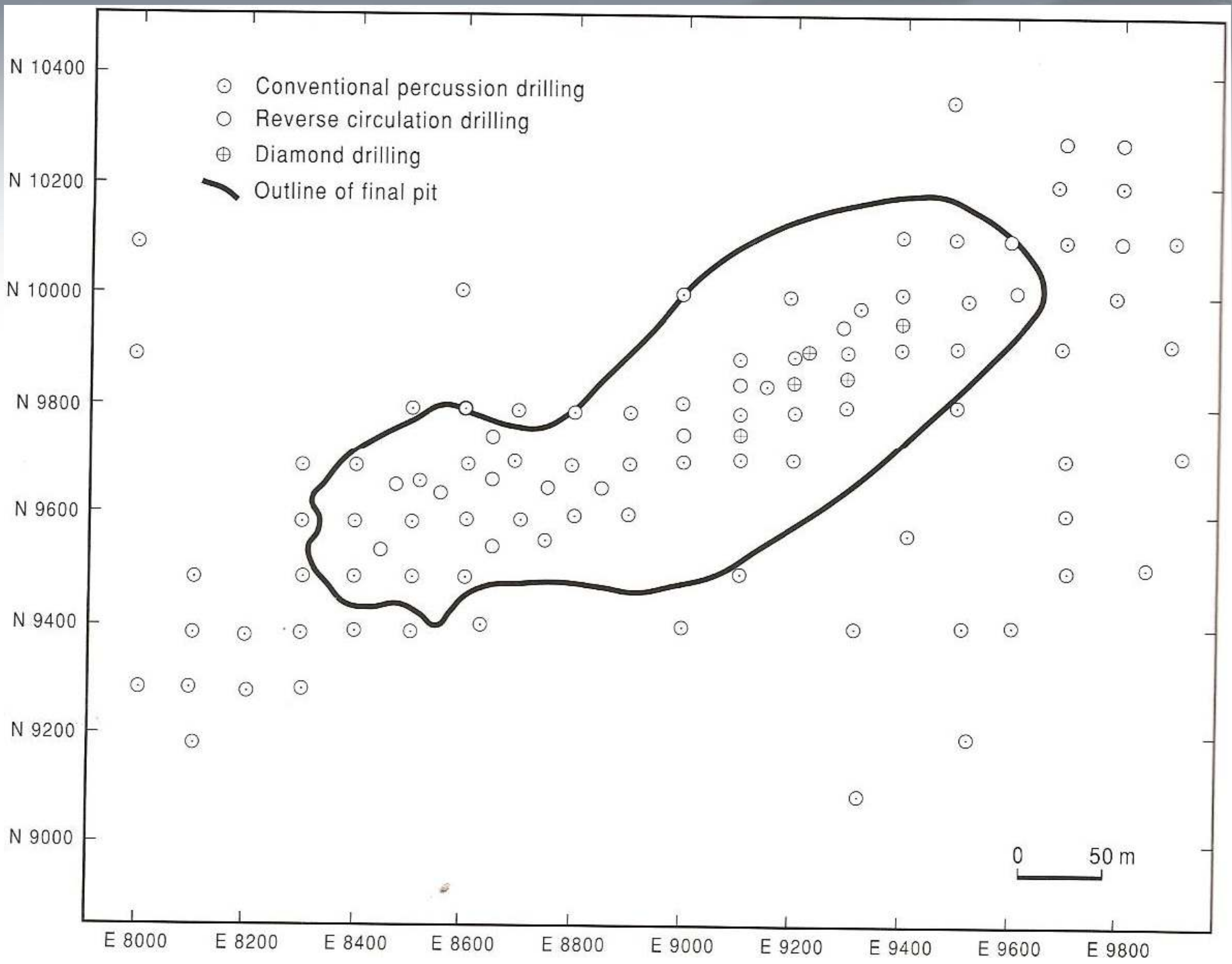

Fig. 16.6 Map showing the location of the exploration boreholes in relation to the final outline of the Trinity mine open pit from which the oxide mineralisation was extracted.

4. The geology of Pershing County and the Trinity District
4.1 Regional setting – Pershing County

- **The Trinity Mining District of Pershing County**
  - Part of the Pacific Rim Metallogenic Belt
  - Mountain ranges reflect the surface expression of major NE-SW structural lineaments sequentially repeated across Nevada
  - Fig. 16.4: Regional geology
  - Table 16.2: Outline of silver deposits of Nevada
    Disseminated type/ vein type / Carbonate type
  - The Auld Lang Syne Group (ALSG) forms the majority of the Triassic sedimentary sequence and reflects the shallow marine conditions of a westerly prograding delta

Table 16.2

	Disseminated	Vein	Trinity
Host rock	Tertiary felsic volcanics and clastic sediments, Devonian limestone	Tertiary andesites and rhyolites	Teritary porphyry rhyolite, minor occurrence in tuff, and argillite
Type of mineralisation	Discrete grains and vein stockworks	Banding in quartz veins	Disseminations, microfractures, veinlets, and breccia infill (vein stockwork)
Morphology	Tabular, podiform bodies, defined by assay cut-off of $<300\ g\ t^{-1}$	Veins defined by fault contacts with assay cut-off between 200 and 300 $g\ t^{-1}$. Change in cut-off has little effect on tonnage	Lenticular and stacked tabular, sharp assay boundaries of $<30\ g\ t^{-1}$
Mean grade	270 $g\ t^{-1}$	500–800 $g\ t^{-1}$	160–250 $g\ t^{-1}$
Geological control	Structural, rock permeability and proximity to conduit	Structural and fracture density, intersection of fault and fractures	Structural, rock permeability, fault intersections, percentage fracture density
Zoning	Increased mineral content with depth, high Pb–Zn–Mn, low Au, Ag:Au>100	Sharp vertical zoning, sulfides increase with depth, Ag:Au>50	Sulfide-oxide zoning, high Ag:Au
Mineralogy	Acanthite, tetrahedrite, native Ag, pyrite and Pb–Zn base metals	Acanthite, low pyrite and sulfide content	Sulfides: friebergite–pyragyrite, chalcopyrite, pyrite, stannite. Oxides
Alteration	Silica–sericite (carbonate, clay, chlorite, potassic feldspar)	Extensive and variable, hematite–magnetite, propylitic, adularia and illite	Silicification, adularia–quartz–sericite, minor propylitic, illite and kaolinite
Process of formation	Hypogene	Hypogene, hydrofracturing, and brecciation	Epithermal and hydrotectonic fracturing
Hydrothermal solutions	165–200°C, 5 wt% NaCl, low salinity groundwater mixing with oilfield brines and wall rock alteration	200–300°C, meteoric solutions, precipitation induced by mixing, boiling	Not available

Table 16.2 Outline of silver deposits of Nevada, including a comparison with the Trinity deposit

4. The geology of Pershing County and the Trinity District
4.2 The geology of the Trinity Mine

- **Stratigraphy**

Age	Unit name	Lithologies	Intrusions
Quaternary	Surficial deposits	Gravel, alluvium, and colluvium	
Pleistocene	Volcanics, fluvial deposits, Upper Tuff	Basalt, fanglomerates and channel sands, phreatic-clastic welded and unwelded, tuff	Latitic and rhyolitic dykes
Tertiary (early Pliocene)	Rhyolite porphyry	Rhyolite flows, agglomerates, and breccias	Rhyolitic, exogenous domes, porphyritic to aphanitic
	Lower tuff	Epiclastic and pyroclastic airfall, reworked tuff	
Cretaceous	Argillite breccia	Subangular to angular argillite clasts (1–10 cm) in fine-grained matrix. Breccia is gradational, tectonic in origin, and fault associated	Granodiorite, medium-grained, hypidiomorphic (90 Ma)
Triassic–early Jurassic	Auld Lang Syne Group	Shelf and basin facies. Shale, siltstone, slate, phyllites, and argillites. Siliceous and carbonaceous sandstones and limestones. Quartzites	

Table 16.3 Stratigraphy of the Trinity area.

4. The geology of Pershing County and the Trinity District
4.2 The geology of the Trinity Mine

- **Structural geology**
  - The structural history of the Trinity area appears to be one of initial NE trending block faults and associated thrusts and shear zones, later offset by NW trending normal faults
- **Alteration**
  - Sericitization, silicification and quartz-adularia-sericite (QAS) alteration tends to be most intense along faults, within permeable lithologies and breccia zones
- **Mineralisation**
  - Ag mineralisation in Pershing County: within breccias peripheral to rhyolite domes with mineralisation concentrated in microfractures
  - Trinity Ag orebody: hydrothermal, volcanic hosted, silver-base metal deposit

5. Development and mining

- **The exploration drilling program**
  - Drilling continued during mining to confirm ore reserves.
- **Pit design**
  - Pit modification was required during mining to improve ore control, slope stability, ore shoot excursion, and operational access
  - Final pit dimensions: 427 x 152 x 75 m/ 4.5 m benches attaining slopes of 60-72 degrees
  - Haulage ramps: 16.5 m wide with 1.2 m berms, maximum gradient 10%
- **Grade control**
  - Based upon the blasthole samples and pit geology
  - silver grade (4 groups): (i) ore at > 45 g/t (ii) low grade ore at 31-45 g/t (iii) lean ore at 17-31 g/t (iv) waste at < 17 g/t
  - $\frac{AAS - CN \times 100}{AAS}$ Oxide ore: 6-17%
    Sulfide ore: 24-40%

6. Mineral processing

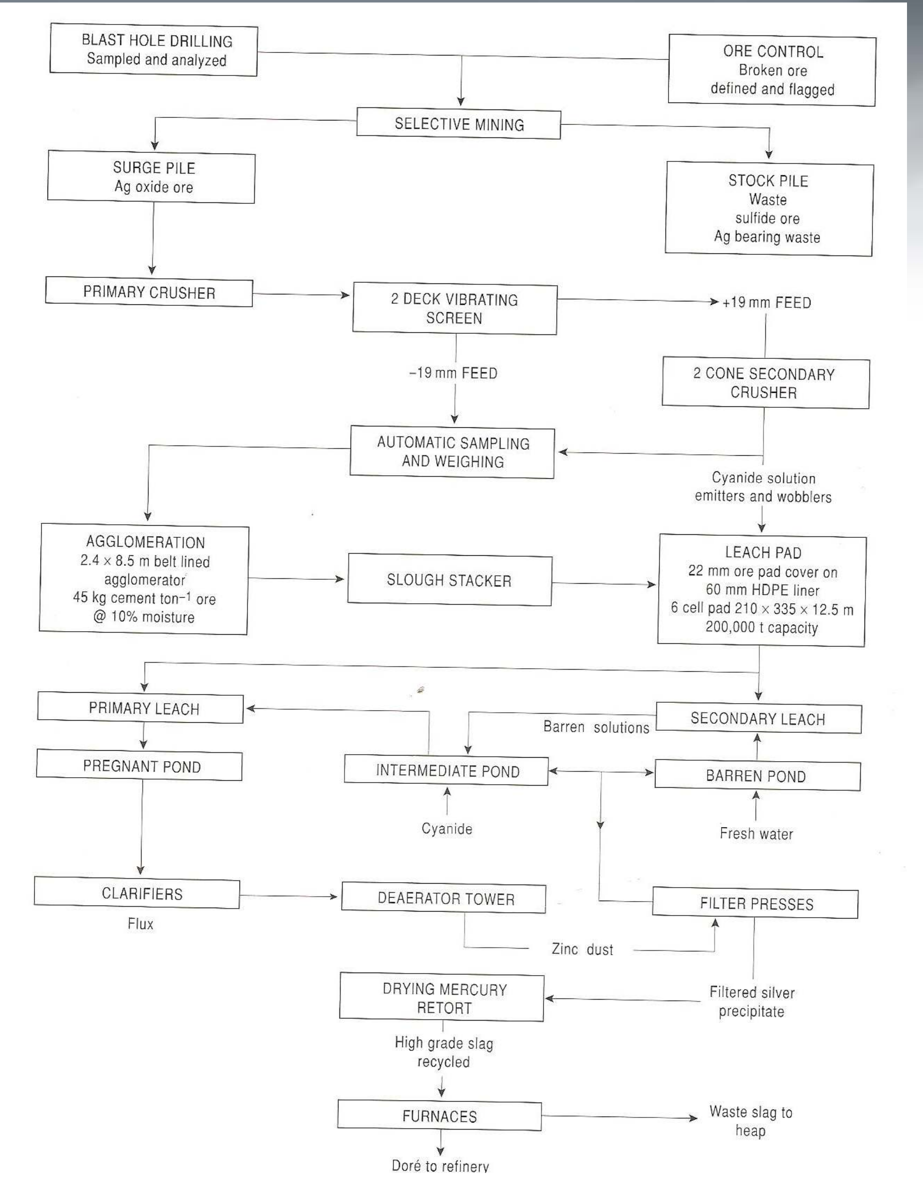

Fig. 16.9 A diagrammatic flow sheet of the mining and processing of the ore at the Trinity Mine, Nevada

7. Environmental consideration
7.1 Natural degradation and detoxification

- **Alternatives to cyanide degradation and heap detoxification**
  - Natural processes
  - Chemical treatment
- **Passive abandonment**
  - High UV levels and strong winds for 9 months of the year
  - Fast in the near-surface layers, slow rapidly with depth
- **Rinsing with barren solutions**
  - In laboratory: a column was rinsed with fresh water and the cyanide levels were reduced from 700 to 50 ppm
  - It took between 12 and 21 months to achieve and extremely large quantities of water (4500 L/t) were required

7. Environmental consideration
7.2 Chemical treatment & 7.3 Summary

- **Acid leach**
  - Leachate collected in the ponds, neutralized with lime, metals would be removed mechanically
- **Sulfur dioxide and air oxidation method (INCO)**
  - Conjunction with lime and a copper catalyst
- **Alkaline chlorination**
  - Chlorine gas or calcium hypochlorite are sued in the oxidation process
- **Hydrogen peroxide oxidation**
  - H_2O_2 is added to the recirculation pond and cyanide-free water is recirculated through the heap using the original sprinkler system
- **Ferrous sulfate**
  - 1 mole of ferrous sulfate ties up 6 moles of cyanide to produce Prussian Blue

8. Grade estimation

- **It is essential for reliable ore reserve calculations to derive the best Ag grade estimate for an orebody**
- **The 5220 bench of the Trinity silver deposit**
  - 1390 blasthole samples
  - No spatial bias or clustering effects due to the regular sample pattern

- **Univariate statistics**
- **Outlier and cut-off grade evaluation**
- **Spatial distribution**
- **Semi-variograms**

8. Grade estimation
8.1 Univariate statistics

	Total population	Excluding >20 oz t^{-1} Ag	1.3–20 oz t^{-1} Ag
Number of assays	1390	1385	309
Mean	1.43 (49)	1.30 (45)	4.65 (159)
Median	0.33 (11)	0.33 (11)	2.30 (79)
Trimean	0.48 (16)	0.48 (16)	3.45 (118)
Sichel-T	1.28	1.22	4.52
Variance	13.59	6.93	16.36
Standard deviation	3.69	2.63	4.04
Standard error	0.10	0.07	0.36
Skewness	10.62	3.89	1.84
Coefficient of variance	2.58	2.02	0.87
Lower quartile	0.16 (5)	0.16 (5)	1.90 (65)
Upper quartile	1.11 (38)	1.09 (37)	5.84 (200)
Interquartile range	0.95 (33)	0.93 (32)	3.93 (135)

Silver values are in oz t^{-1} (g t^{-1}).

Table 16.4
Univariate statistics of the silver values derived from cyanide leach analysis of the blasthole samples on the 5220 level, Trinity Mine, Nevada

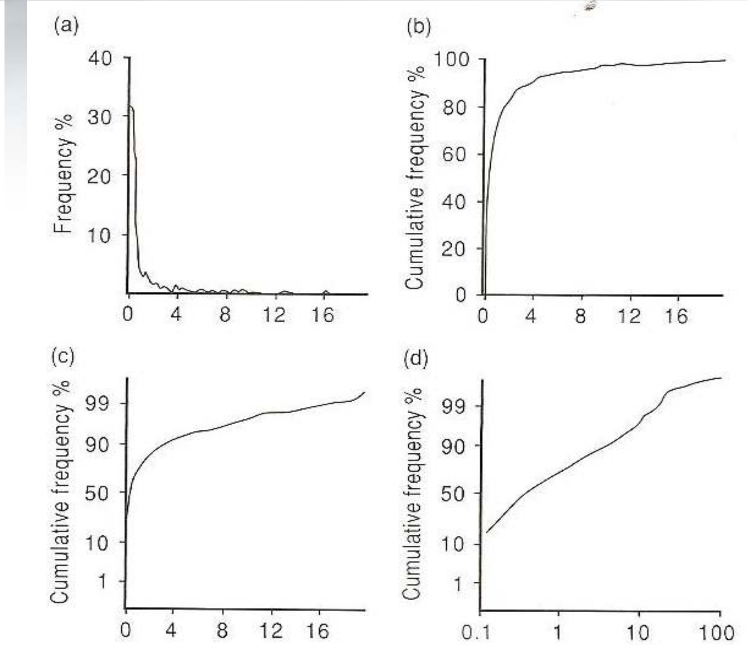

Fig. 16.10
(a)Histogram of silver values
(b)Cumulative frequency plot
(c)Normal probability plot
(d)Log-normal probability plot

8. Grade estimation
8.1 Univariate statistics

	Silver values in oz t^{-1} (g t^{-1})					
	0.0–0.4	**0.4–0.8**	**0.8–1.3**	**1.3–5**	**5–10**	**10–20**
Number of assays	762	212	1032	215	731	
Mean	0.18 (6)	0.57 (20)	1.03 (35)	2.56 (88)	7.46 (256)	14.37 (493)
Median	0.17 (6)	0.55 (19)	1.01 (35)	2.25 (77)	7.34 (252)	13.60 (466)
Trimean	0.17 (6)	0.56 (19)	1.02 (35)	2.35 (81)	7.44 (255)	13.93 (478)
Sichel-T	0.20	0.57	1.03	2.56	7.46	14.37
Variance	0.01	0.01	0.02	1.04	2.48	10.79
Standard deviation	0.10	0.11	0.15	1.02	1.57	3.28
Standard error	0.00	0.01	0.02	0.07	0.21	0.58
Skewness	0.19	0.28	0.19	0.74	0.08	0.25
Coefficient of variance	0.55	0.19	0.15	0.40	0.21	0.23
Lower quartile	0.10 (3)	0.47 (16)	0.89 (31)	1.71 (59)	5.98 (205)	11.18 (383)
Upper quartile	0.26 (9)	0.67 (23)	1.16 (40)	3.20 (110)	9.09 (312)	16.70 (573)
Interquartile range	0.16 (6)	0.20 (7)	0.27 (9)	1.49 (51)	3.11 (107)	5.52 (189)

Table 16.5
Univariate statistics of the subpopulation of the silver values derived from cyanide leach analysis of the blasthole samples on the 5220 level, Trinity Mine, Nevada

8. Grade estimation
8.2 Outlier and cut-off grade evaluation

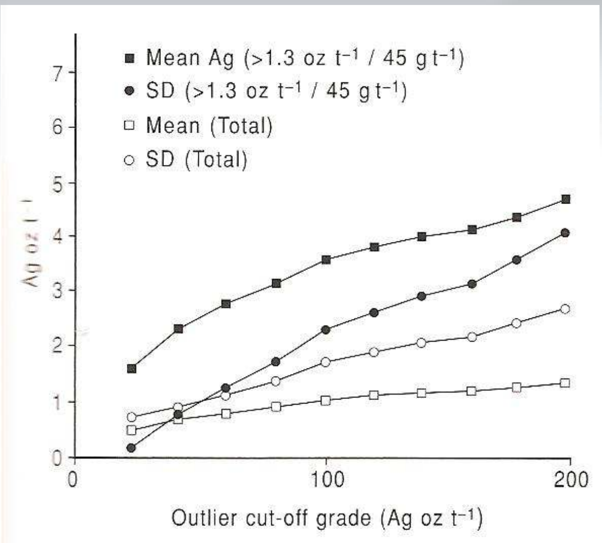

Fig. 16.12 Graph showing changes in mean grade and standard deviation when different outlying (high) grades are removed from the database of the silver values

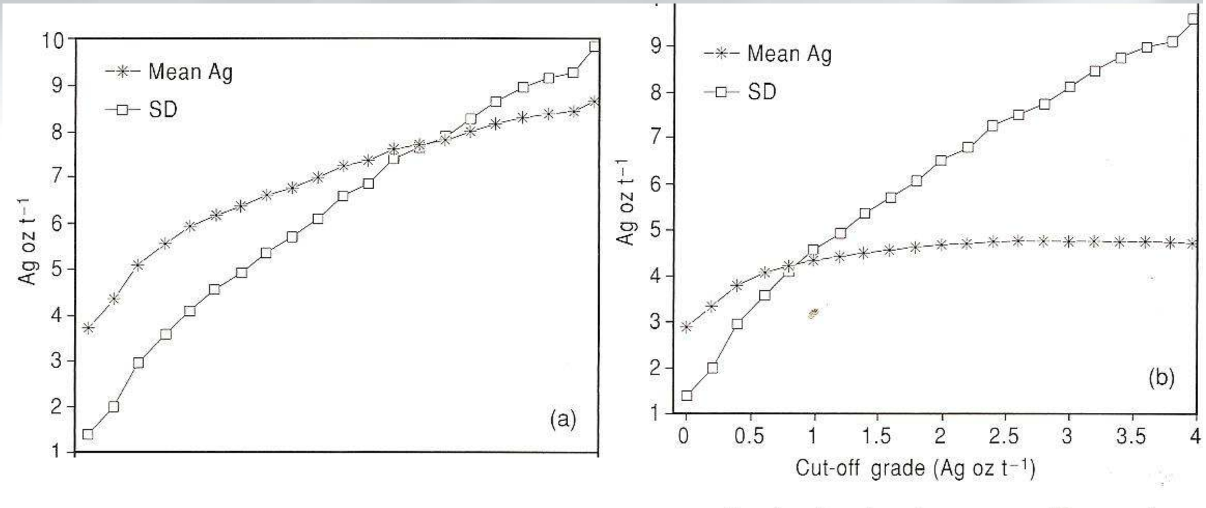

Fig. 16.13 Graphs showing the average silver grade when varying cut-offs are applied to the database of the silver values
(a)Total population
(b)With values >20 oz/t removed.

8. Grade estimation
8.3 Spatial distribution

- **A contour map of the 5220 level**
  - E-W trend to the data which fragments and changes to a NW-SE trend to the west

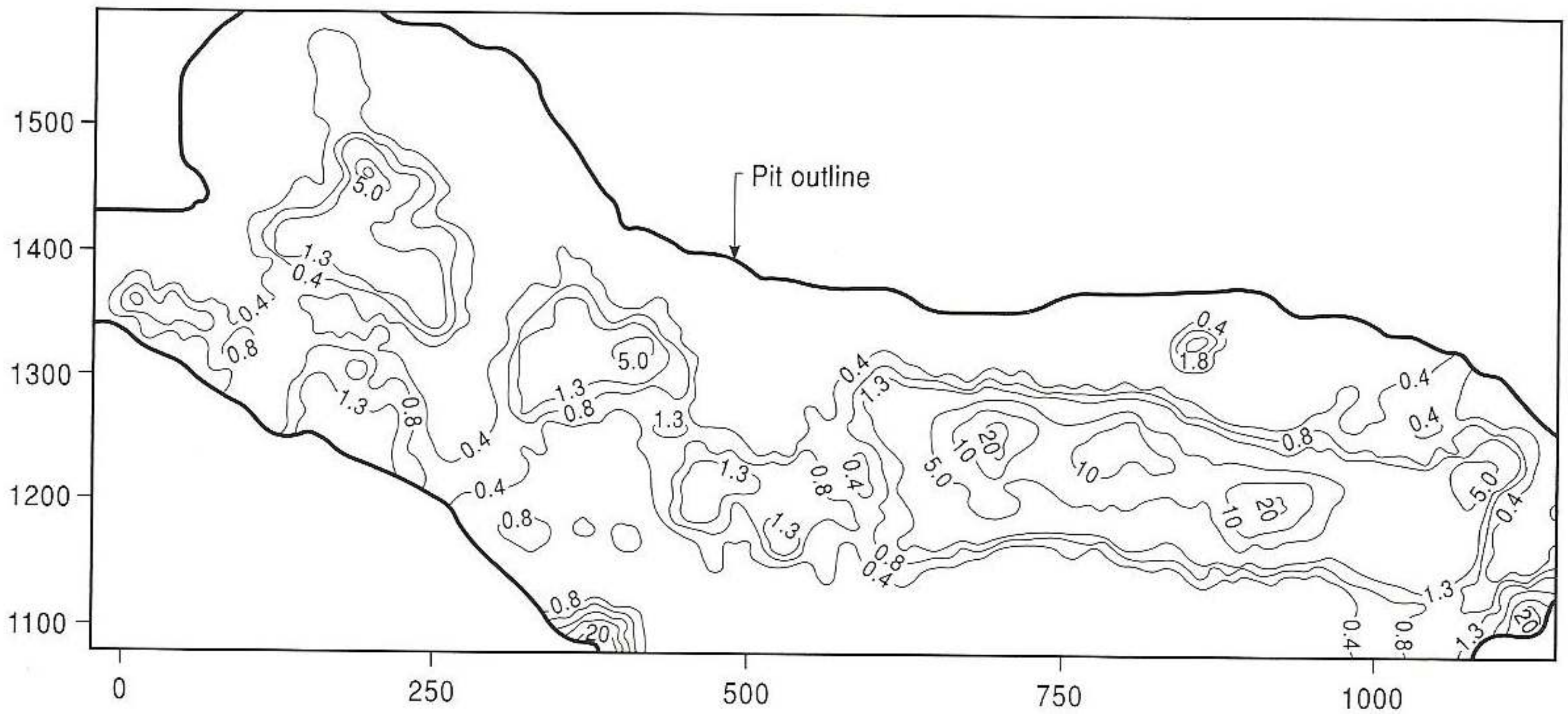

Fig. 16.14 A contour map of the silver grades

8. Grade estimation
8.3 Spatial distribution

- **Zonal arrangement**
  - Spatial integrity of the subgroups, illustrating the concentric zoning and isolated grouping of the data

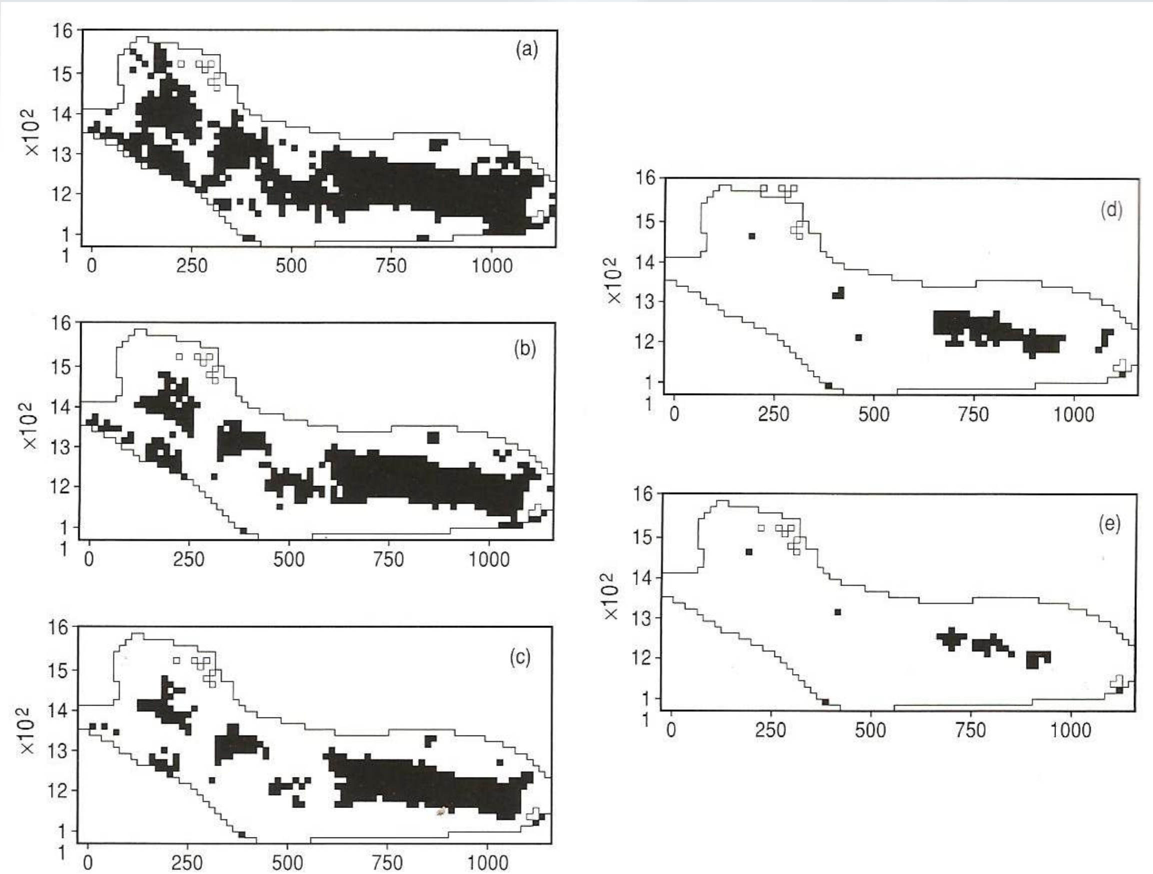

Fig. 16.15 Indicator maps of the Ag grades
(a) 0.4 (b) 0.8 (c) 1.3 (d) 5.0 (e) 10.0 oz/t

Fig. 16.16

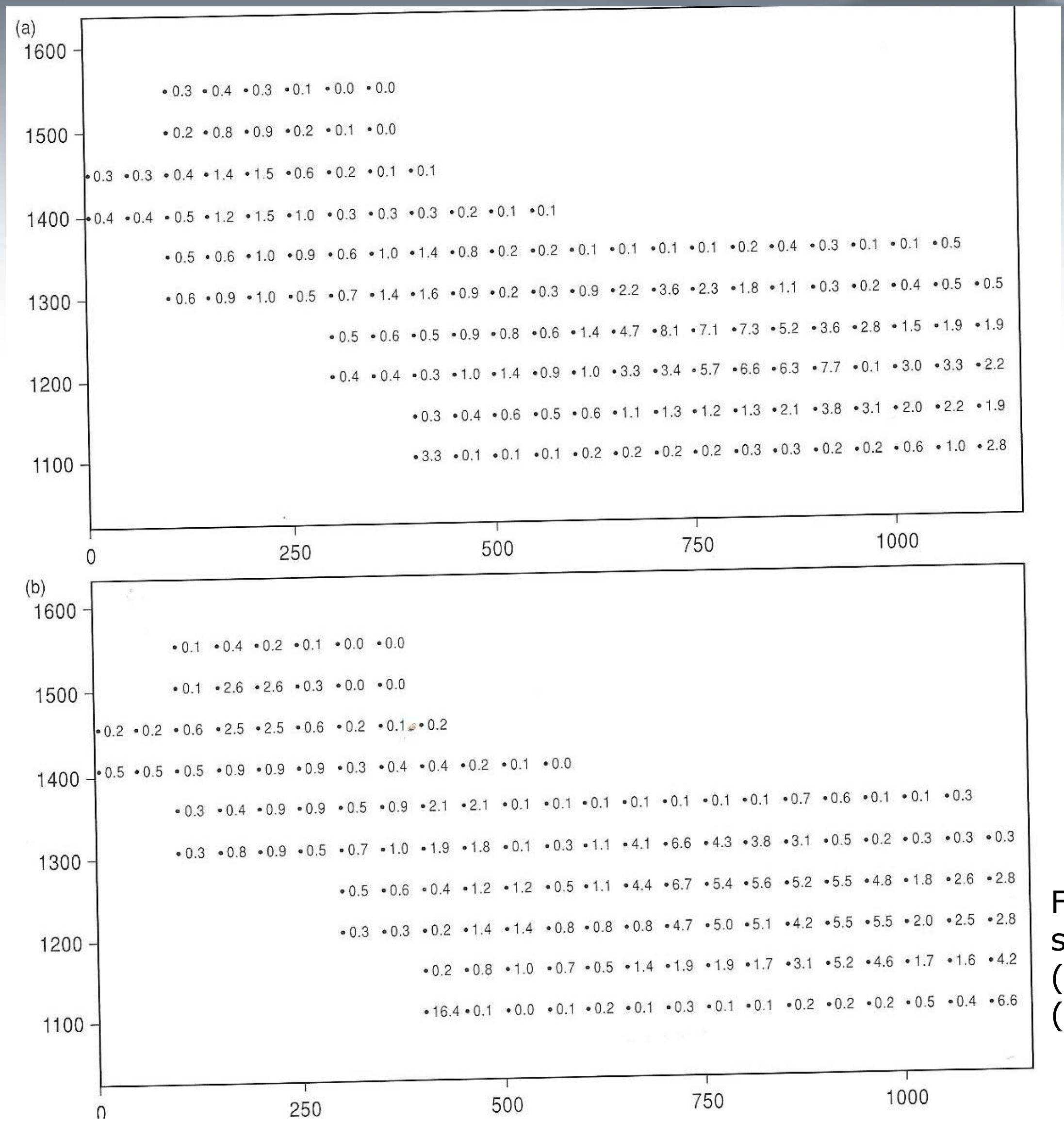

Fig. 16.16 Window statistics performed on the silver grades of the 5220 bench.
(a)Mean Ag oz/t
(b)Standard deviation

Fig. 16.17

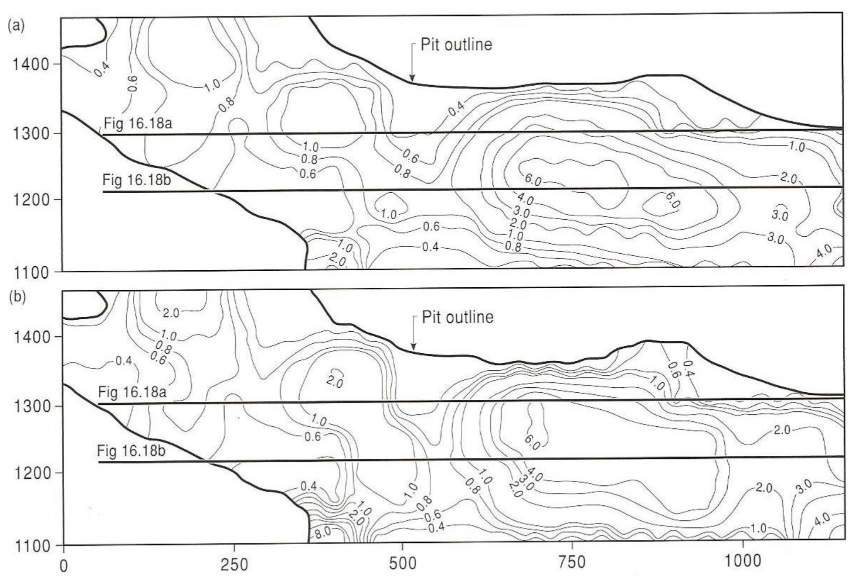

Fig. 16.17 Window statistics performed on the silver grades of the 5220 bench
(a)Contours of mean Ag oz/t
(b)Contours of standard deviation

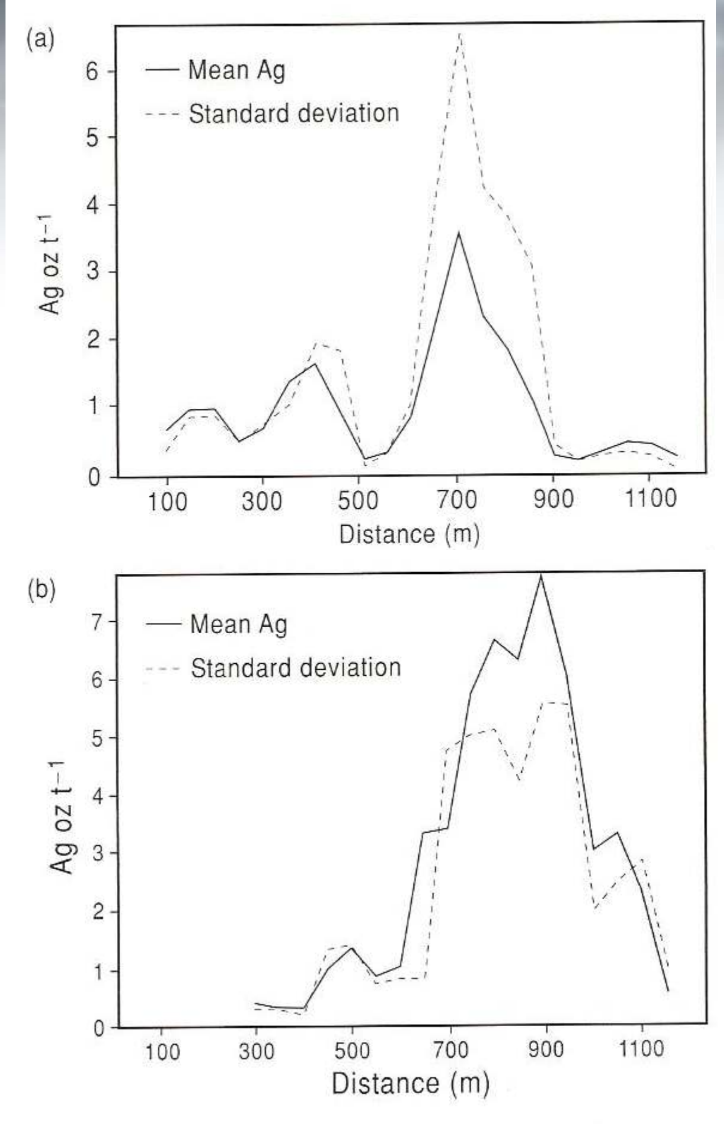

Fig. 16.18 Profile 1 and 2 of the window mean standard deviation showing the proportional effect and highlighting areas of expected high error

8. Grade estimation
8.4 Semi-variogram

- To quantify the spatial continuity of the data
- Directional semi-variograms show different rages in different section

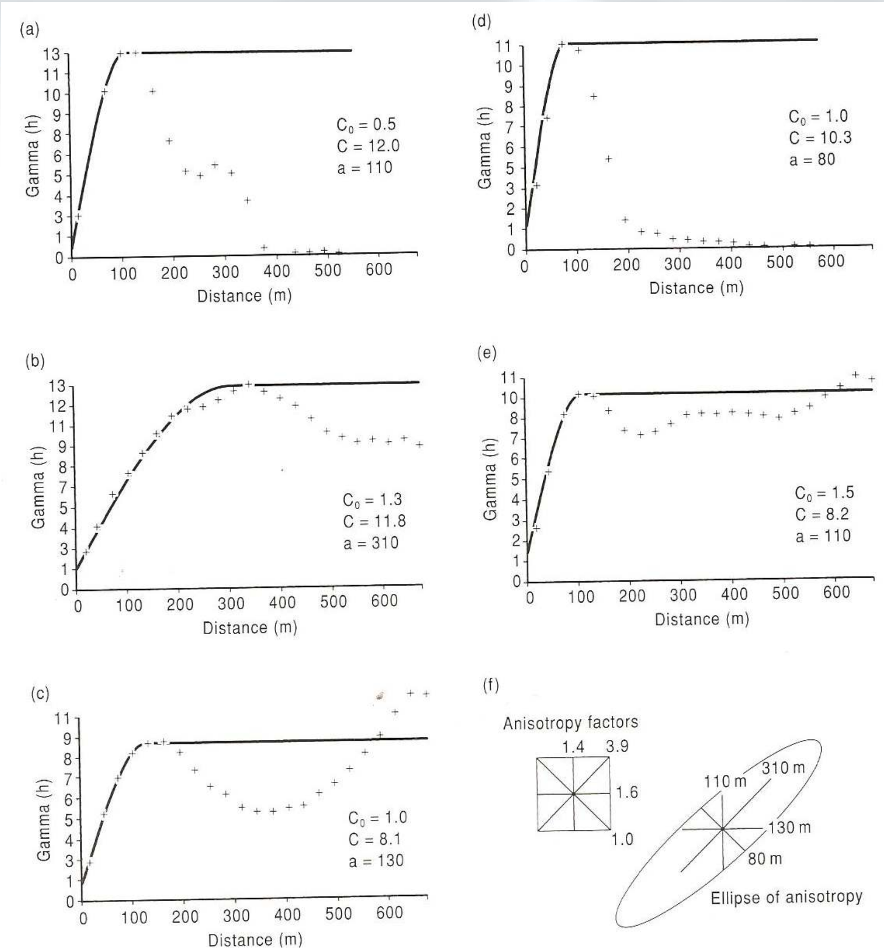

Fig. 16.19 Semi-variograms for the silver assays of the 5220 bench
(a)N-S direction
(b)NE-SW direction
(c)E-W direction
(d)SE-NW direction
(e)Omni-directional
(f) Ellipse of anisotropy and anisotropy factors

8. Grade estimation
8.5 Conclusions

- To improve the grade estimation it is necessary to try to establish normal distributions within the whole skewed population
- The variability within each subpopulation is thus reduced, which increases the confidence in the subpopulation mean
- Indicator maps show that subgroups, as defined by statistical parameters, are spatially arranged
- From the univariate statistics and spatial distribution of the data the conclusion is that a global estimate must be derived from local estimates rather than the whole population

9. Ore reserve estimation
9.1 Evaluation of initial exploration data
9.2 Evaluation of additional exploration data

- **During the 1982-1983 exploration program**
  - The oxide mineralisation had not been fully evaluated, and the initial reserve estimates only took the sulfide mineralisation into account
- **Additional exploration drilling in 1986**
  - A small area of high grade silver oxide mineralisation could possibly support a heap leach operation
  - The reserve potential of the oxide zone was calculated by several members of the joint venture, using different methods and cut-off grades

Table 16.6 Summary of the ore reserve calculation for the silver oxide zone

Method	Tonnage factor $ft^3\ t^{-1}$ (SG)	Composite length ft (m)	Ag cut-off grade $oz\ t^{-1}$ ($g\ t^{-1}$)	Tonnage $\times 10^6$	Average Ag grade $oz\ t^{-1}$ ($g\ t^{-1}$)	Total Ag oz (g) $\times 10^6$
Polygons–USB	13.3 (2.41)	20 (6.1)	1.5 (50)	0.967	6.95 (238)	6.22 (213)
N–S cross-sections, USB	13.3 (2.41)	10 (3.0)	1.5 (50)	1.304	6.16 (211)	8.03 (275)
E–W cross-sections, USB	13.3 (2.41)	10 (3.0)	1.5 (50)	1.293	5.90 (200)	7.63 (262)
N–S cross-sections, USB	13.3 (2.41)	10 (3.0)	1.5 (50)	0.932	7.69 (264)	7.17 (246)
Polygons, Santa Fe	13.3 (2.41)	20 (6.1)	3.0 (100)	0.669	9.10 (310)	6.09 (209)
N–S cross sections, Santa Fe and USB	13.3 (2.41)	10 (3.0)	2.0 (69)	0.870	8.00 (274)	6.96 (240)

9. Ore reserve estimation
9.3 Reserve estimate for mine planning

- **3D block modeling techniques**
  - In 1987, to estimate reserves and the data for mine planning
  - A conventional 2D inverse distance squared ($1/D^2$) technique was used to interpolate grades from borehole information

Table 16.7 Reserve estimates on the silver oxide zone, using the $1/D^2$ block model

Tonnage $\times 10^6$	Tonnage factor $ft^3\ t^{-1}$ (SG)	Composite length ft (m)	Ag cut-off grade oz t^{-1} ($g\ t^{-1}$)	Average Ag grade oz t^{-1} ($g\ t^{-1}$)
2.65	13.7 (2.34)	15 (4.5)	0.5 (17)	3.05 (105)
2.05	13.7 (2.34)	15 (4.5)	1.0 (34)	3.76 (129)
1.65	13.7 (2.34)	15 (4.5)	1.5 (50)	4.46 (153)
1.26	13.7 (2.34)	15 (4.5)	2.0 (69)	5.19 (178)
0.88	13.7 (2.34)	15 (4.5)	3.0 (100)	6.33 (217)
0.63	13.7 (2.34)	15 (4.5)	4.0 (137)	7.52 (258)

9. Ore reserve estimation
9.4 Updated tonnage and grade estimate
9.5 Grade control and ore reserve estimation using blastholes

- **An updated reserve estimate**
  - Hand-calculated using cross-sections to evaluate the discrepancy

Table 16.8 Updated reserve estimates on the silver oxide zone

Method	Tonnage factor $ft^3\ t^{-1}$ (SG)	Composite length ft (m)	Ag cut-off grade $oz\ t^{-1}$ ($g\ t^{-1}$)	Tonnage $\times 10^6$	Average Ag grade $oz\ t^{-1}$ ($g\ t^{-1}$)	Total Ag oz (g) $\times 10^6$
N–S cross-sections	13.7 (2.34)	15 (4.5)	1.5 (50)	0.899	6.94 (238)	6.24 (214)
Bench plans*	13.7 (2.34)	15 (4.5)	1.6 (55)	0.859	7.33 (251)	6.29 (216)
Blocks $15 \times 15 \times 15$ ft ($4.5 \times 4.5 \times 4.5$ m)	13.7 (2.54)	15 (4.5)	1.6 (55)	0.963	6.55 (225)	6.31 (217)

* These estimates exclude the first three benches which had already been mined out.

- **Mine grade control**
  - By sampling and assaying the blasthole cuttings
  - A final reserve was calculated using these blocks and a slightly higher reserve with a lower grade was estimated

9. Ore reserve estimation
9.6 Factors affecting ore reserve calculations

- **Geological control**
- **Sampling methods**
- **Cut-off grade**
- **Sample mean**
  - Arithmetic mean probably overestimated the mean in this study but this could have been improved by establishing subpopulations with normal distributions and averaging the estimates from these discrete zones
- **Analytical techniques**
- **Specific gravity**
  - Density was determined on a number of different rock types
- **Mining dilution**
  - Dilution of ore by waste during mining is inevitable but careful grade control will minimize the risk of dilution

10. Summary and conclusion

- The Trinity oxide orebody defined a small but economic silver deposit, amenable to cyanide heap leaching.
- The orebody was fairly continuous to the northeast but became fragmented and fault controlled to the southwest
- The ore zone was defined by stacked tabular to lenticular bodies dipping steeply to the west and northwest and offset by N-S and NW-SE cross-faulting
- Mineralisation tended to be controlled by faulting, alteration, and fracture density.

Thank You !