GEOLOGICAL SURVEY OF NEW SOUTH WALES
DEPARTMENT OF MINERAL RESOURCES

GEOLOGY AND MINERALIZATION OF THE SHUTTLETON AREA, WEST OF NYMAGEE NSW

by

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GS1983/128

PREFACE

This report is the text of a talk presented at a Symposium - "Structure, tectonics and ore genesis at Cobar NSW" - held at the Sixth Australian Geological Convention, Canberra, in February 1983. An abstract to accompany the talk (Suppel and Gilligan 1983) was published in a volume of abstracts for the Convention. The talk was illustrated by slides which are referred to in the text by way of subheadings. These slides have been made into photographic prints for this report and in many cases copies of plans used in preparation of the slides also are presented.

The talk summarizes the main conclusions from studies at Shuttleton as reported by Suppel and Gilligan (in prep) and Suppel (in prep). Dr E Slansky of the Geological Survey of New South Wales undertook X-ray diffraction analyses of numerous chlorite samples for these studies (Slansky 1980) and made further analyses for presentation in the talk. His contributions are gratefully acknowledged. Data from Swiss Aluminium Mining Australia Pty Ltd (1975) were used in preparation of some plans for the talk.

REFERENCES
(Preface)

Slansky, E., 1980 Chlorite from mineral deposits of the Cobar region - characterization by Oinuma's method. New South Wales Geological Survey - Report Mineralogy 1980/81 (unpubl) (GS1980/014)

Suppel, D.W., in prep A study of mineral deposits in the Cobar Supergroup, Cobar region, New South Wales. University of New South Wales - M.Sc. Thesis (unpubl)

Suppel, D.W., and Gilligan, L.B., 1983 Geology and mineralization of the Shuttleton area, west of Nymagee NSW (Abstract) in Lithosphere Dynamics and Evolution of Continental Crust, Sixth Australian Geological Convention Canberra 1983. Geological Society of Australia - Abstract No 9, 316-317

Suppel, D.W., and Gilligan, L.B., in prep The geology and mineral deposits of the Shuttleton-Wirlong area. New South Wales Geological Survey - Report (unpubl) (in prep)

Swiss Aluminium Australia Pty Ltd, 1975 Exploration Licence No. 710, report on exploration and diamond drilling in the South Shuttleton area. Swiss Aluminium Mining Australia Pty Ltd - Report No. 12/75 (unpubl.) (GS1975/171)

ABSTRACT

At Shuttleton copper and minor lead-zinc mineralization is developed in a volcano-sedimentary unit near the base of the Shume Formation, a succession of thickly interbedded sandstone and siltstone within the Cobar Supergroup.

Two sequences are recognised, an eastern and a western, and these are separated by a major northerly striking fault. Mineralization, dominantly pyrite, pyrrhotite and chalcopyrite, is confined to the eastern sequence which consists of a volcanic unit and overlying interbedded shale, siltstone and massive sandstone. The volcanic unit contains a variety of rock types including felsic pyroclastics, lithic tuff, volcaniclastic sediments, shale and sandstone. Strongest mineralization occurs in shale and siltstone in the volcanic unit. There is a broad zoning of iron sulphides; pyrite is most abundant in the volcanic unit and immediately overlying sediments, pyrrhotite tends to occur stratigraphically higher. The sulphide minerals display evidence of different behaviour during deformation; chalcopyrite and pyrrhotite underwent ductile deformation whereas pyrite deformed brittly.

There is a variation in chlorite composition. Analyses by X-ray diffraction reveal a contrast between chlorite in the volcanic unit, especially in strongly mineralized sections, and chlorite in overlying shale and siltstone. This contrast possibly is due to magnesium enrichment of chlorite in the volcanic unit.

Mineralization at Shuttleton is considered to be volcanogenic. Volcanism may have been controlled by a rift-type structure. The deposit was modified by deformation which probably caused a fair degree of remobilization but only over limited distances.

CONTENTS

LIST OF SLIDES/TEXT FIGURES

** Geological and Mining Museum Catalogue Number of 35 mm transparency*

SHUTTLETON

INTRODUCTION

IN THIS TALK WE WILL LOOK AT THE SHUTTLETON COPPER DEPOSITS, DESCRIBING FIRST THEIR REGIONAL GEOLOGICAL SETTING, THEN THE LOCAL GEOLOGICAL SETTING, DEFORMATION AND ALTERATION OF MINERALIZATION AT THE SOUTH SHUTTLETON MINE.

REGIONAL SETTING

SLIDE 1(PRINT)

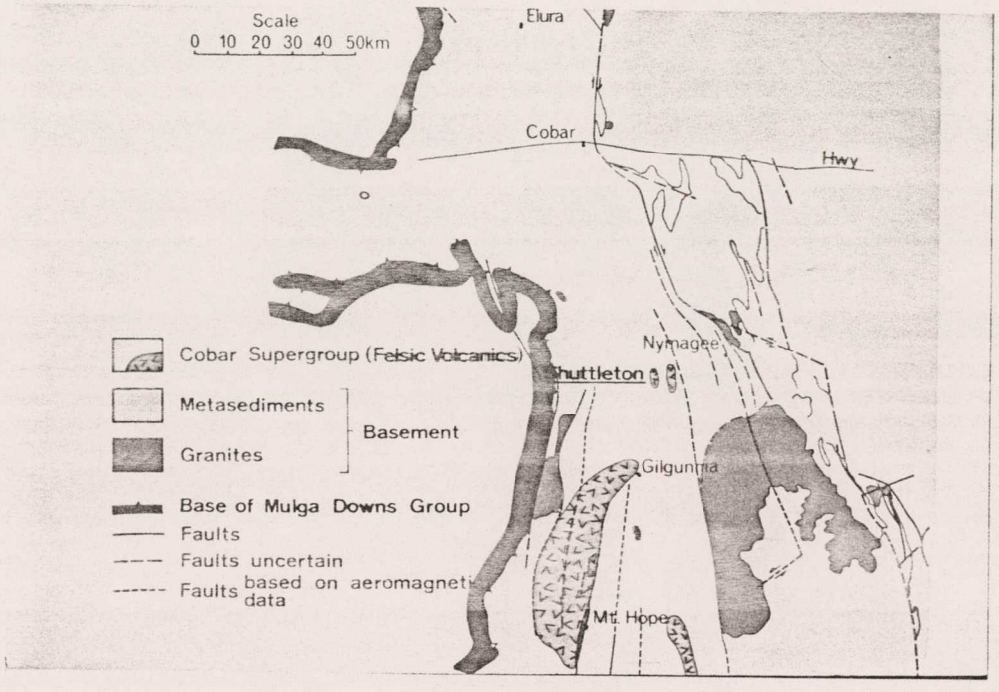
COPPER AND MINOR LEAD-ZINC MINERALIZATION IS DEVELOPED IN FELSIC VOLCANIC ROCKS IN THE COBAR TROUGH AT SHUTTLETON.

THE MAIN OCCURRENCES OF FELSIC VOLCANIC ROCKS IN THE EARLY DEVONIAN COBAR SUPERGROUP IN THE COBAR TROUGH ARE SHOWN ON THIS SLIDE. THERE ARE THREE AREAS. THE TWO IN THE SOUTH OF THE TROUGH, AT MOUNT HOPE AND IN A BELT TO THE EAST RUNNING THROUGH LAKE CARGELLIGO AND TO THE NORTH, POSSIBLY REPRESENT THE REMAINS OF A LARGE COMPOSITE RESURGENT CAULDRON.

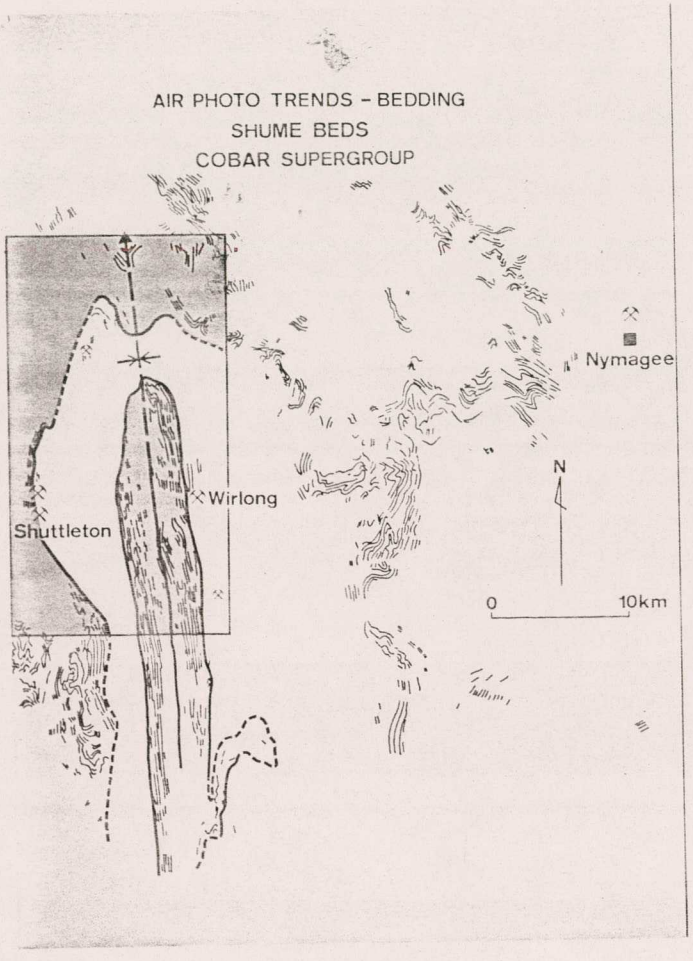
IN THE THIRD AREA, SHUTTLETON, RHYOLITIC AND RHYODACITIC VOLCANICS ARE MORE RESTRICTED AND THE TECTONIC SETTING OF THESE ROCKS IS LESS CLEAR.

SLIDE 2 (PRINT)
SLIDE 2 (PLAN)

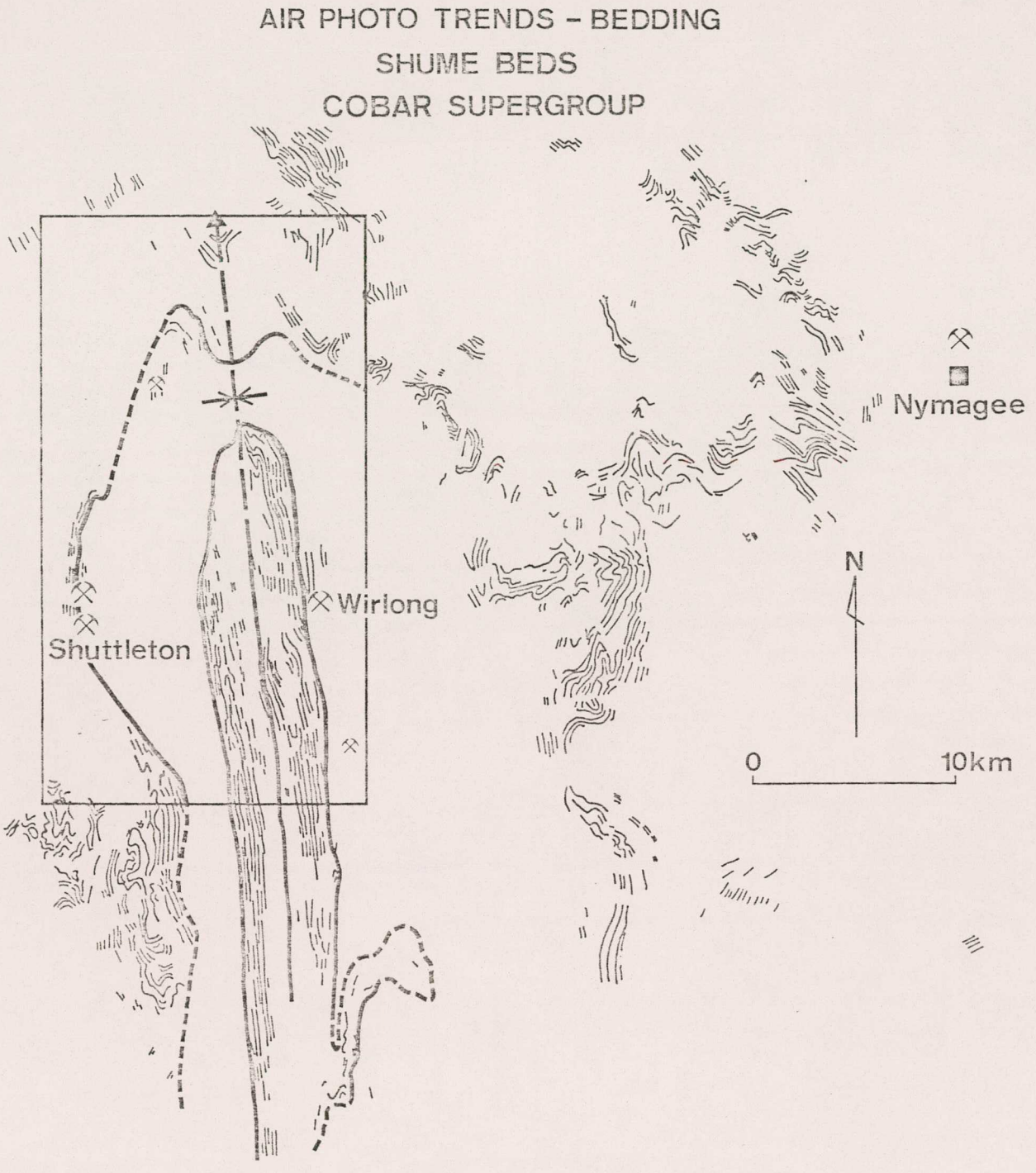
PERHAPS SOME INFERENCES CAN BE DRAWN ABOUT THE STRUCTURAL SETTING FROM THE DISTRIBUTION OF THE SHUME FORMATION IN THE NYMAGEE-SHUTTLETON AREA. THE HOST ROCKS OF MINERALIZATION AT SHUTTLETON ARE CONSIDERED TO BE IN THE LOWER PART OF



SLIDE 1 (PRINT)



SLIDE 2 (PRINT)


AIR PHOTO TRENDS - BEDDING
SHUME BEDS
COBAR SUPERGROUP
Nymagee
Wirlong
Shuttleton
N
0
10km

SLIDE 2 (PLAN)

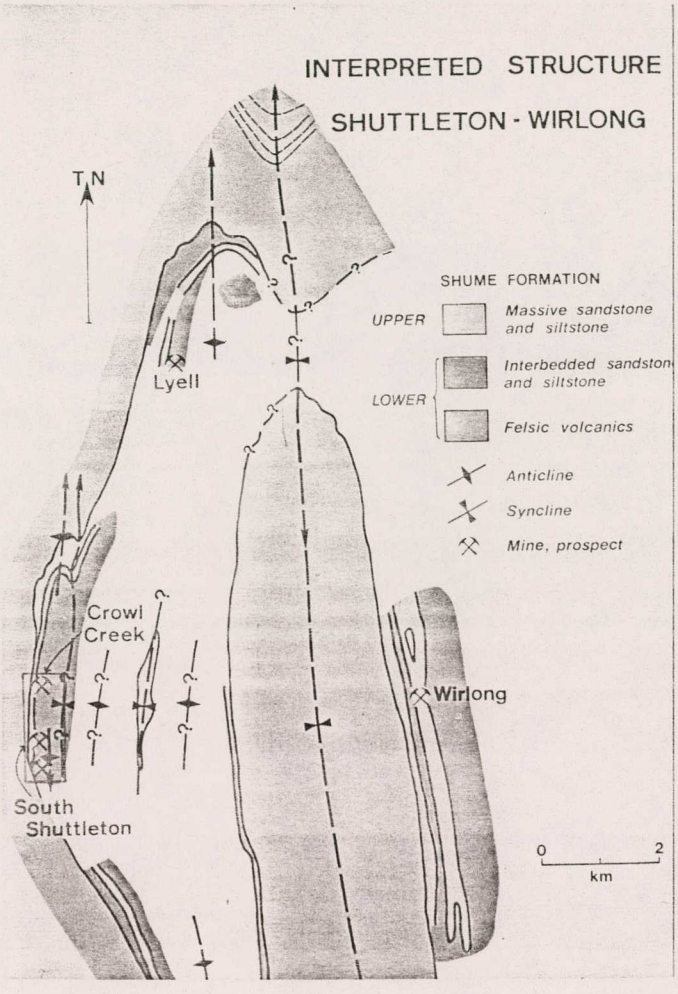
THE SHUME FORMATION WHICH CONSISTS DOMINANTLY OF THICKLY BEDDED QUARTZ SANDSTONE AND SILTSTONE. THESE ROCKS SHOW A PROMINENT BEDDING PATTERN ON AERIAL PHOTOGRAPHS. THE BEDDING TRENDS APPARENT ON PHOTOMOSAICS ARE SHOWN ON THIS SLIDE.

MINERAL DEPOSITS OCCUR IN FELSIC VOLCANIC ROCKS AT SHUTTLETON AND WIRLONG IN THE AREA OUTLINED ON THE SLIDE. BETWEEN SHUTTLETON AND WIRLONG SANDSTONE AND SILTSTONE OF PART OF THE SHUME FORMATION, SHOWN IN BROWN, OCCUPY A TIGHT CONTINUOUS MERIDIONAL FOLD WHICH IS INTERPRETED TO BE A SYNCLINORIUM. TO BOTH THE EAST AND WEST OF THE SHUTTLETON-WIRLONG AREA BEDDING TRENDS IN THE SHUME OUTCROPS, PROBABLY EQUIVALENT TO THOSE SHOWN IN BROWN, ARE MUCH MORE VARIABLE AND POSSIBLY REFLECT BROAD, SHALLOW FOLDS.

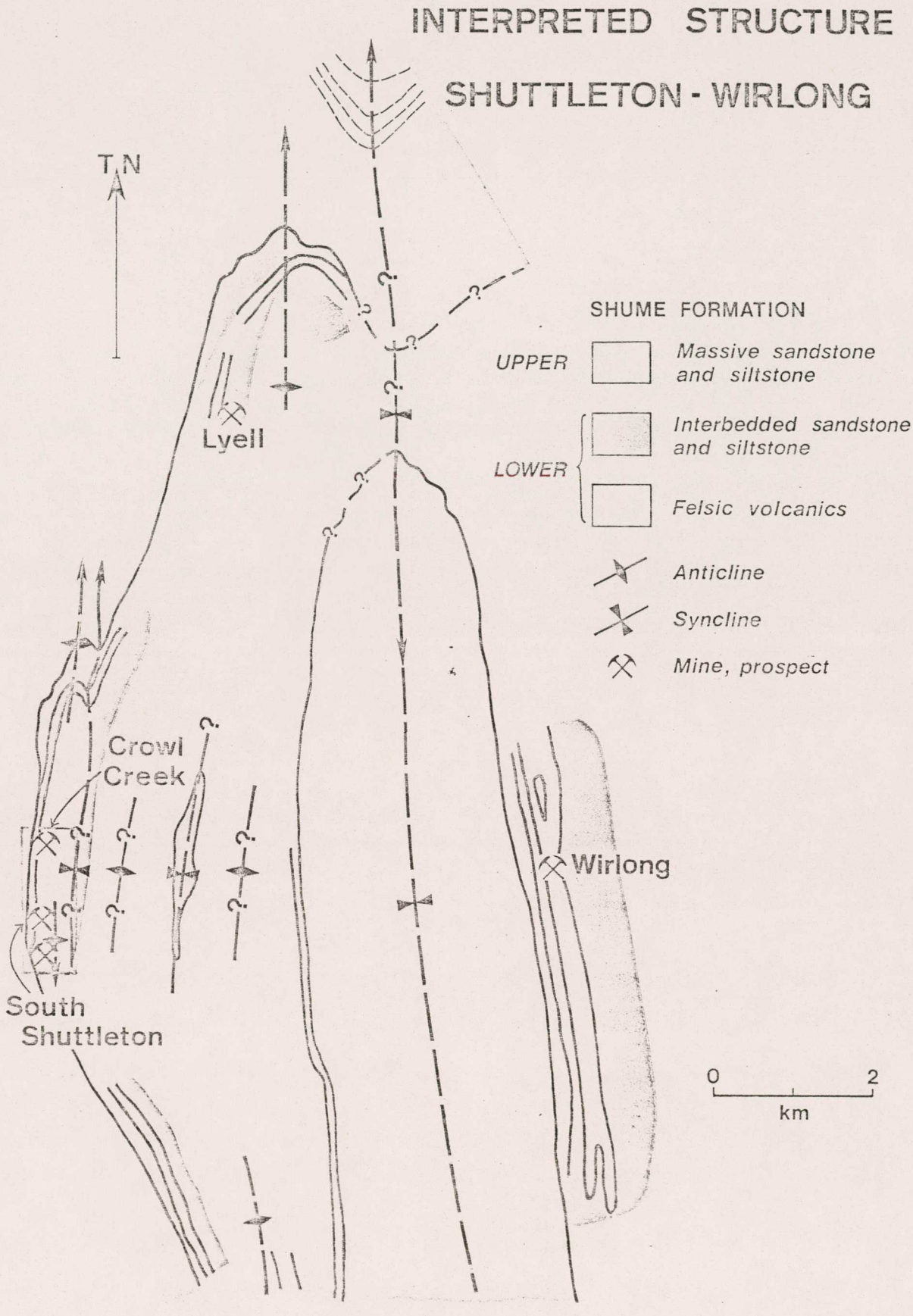
THIS CONTRAST MAY INDICATE THE EXISTENCE OF A STRUCTURAL OR TECTONIC FEATURE, FOR EXAMPLE A RIFT, WHICH CONTROLLED THE VOLCANISM IN THE SHUTTLETON-WIRLONG AREA, AND CAUSED THE RELATIVELY TIGHT MERIDIONAL FOLDING IN THE SHUTTLETON-WIRLONG AREA, IN CONTRAST WITH THE OPEN FOLDING AND SHALLOW DIPS ELSEWHERE.

SLIDE 3 (PRINT)
SLIDE 3 (PLAN)

THE SETTING OF THE SHUTTLETON-WIRLONG AREA IS SHOWN ON THIS SLIDE. AGAIN, THE TIGHT FOLD IN THE MASSIVE SANDSTONE AND SILTSTONE OF THE SHUME FORMATION IS SHOWN, FLANKED BY FELSIC VOLCANICS WHICH WE THINK ARE AT THE SAME STRATIGRAPHIC LEVEL AT WIRLONG IN THE EAST AND IN THE SHUTTLETON AREA IN THE WEST. THESE VOLCANICS, TOGETHER WITH INTERBEDDED SANDSTONE AND SILTSTONE PROBABLY UNDERLIE THE MASSIVE SANDSTONE AND SILTSTONE SHOWN IN BROWN.



SLIDE 3 (PRINT)


INTERPRETED STRUCTURE
SHUTTLETON - WIRLONG
T.N
Lyell
Crowl Creek
South Shuttleton
Wirlong
SHUME FORMATION
UPPER
Massive sandstone and siltstone
LOWER
Interbedded sandstone and siltstone
Felsic volcanics
Anticline
Syncline
Mine, prospect
0
2
km

SLIDE 3 (PLAN)

GEOLOGY

SLIDE 4 (PRINT
SLIDE 4 (PLAN)

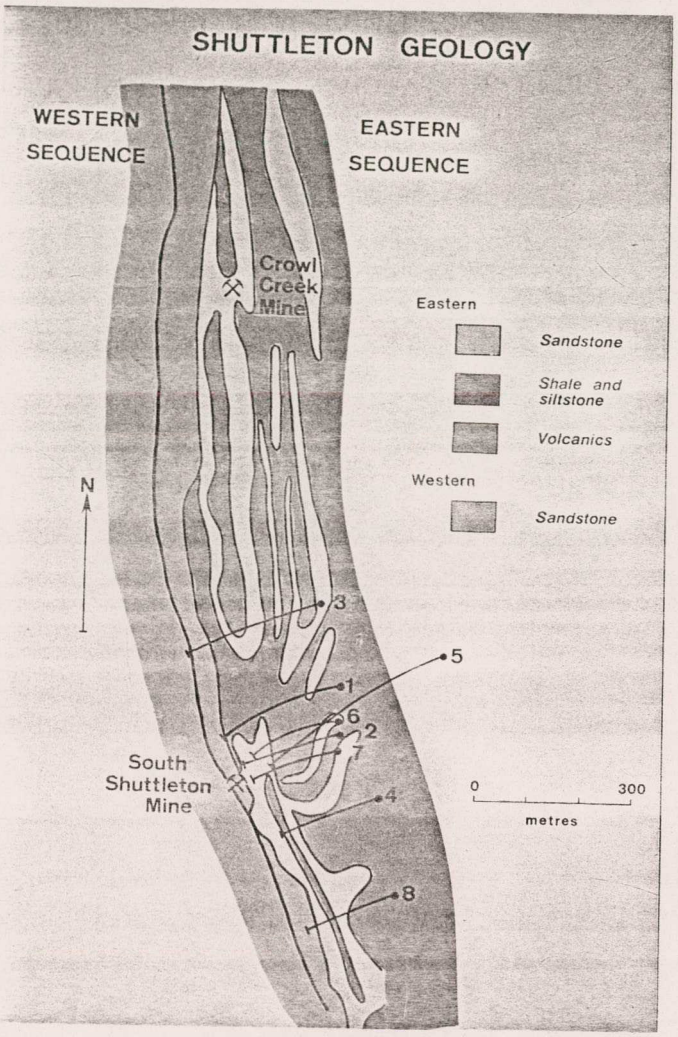
THE MINES AT SHUTTLETON AND SOUTH SHUTTLETON - SHOWN AS THE CROWL CREEK AND SOUTH SHUTTLETON MINES ON THIS SLIDE - WERE ONLY MODEST PRODUCERS; ABOUT 4 450 T OF COPPER. THE BULK OF THIS CAME FROM THE CROWL CREEK MINE.

TWO SEQUENCES HAVE BEEN RECOGNISED IN THE SHUTTLETON AREA; AN EASTERN AND WESTERN, SEPARATED BY A MAJOR NORTHERLY TRENDING FAULT. THE EASTERN SEQUENCE CONSISTS OF A VOLCANIC UNIT WHICH CONTAINS FELSIC PYROCLASTICS, LITHIC TUFFS, VOLCANICLASTIC SEDIMENTS, SHALE AND SANDSTONE. THIS IS A HETEROGENEOUS UNIT ADJACENT TO THE FAULT AND IS OVERLAIN TO THE EAST BY A SEDIMENTARY SUCCESSION OF INTERBEDDED SHALE, SILTSTONE AND MASSIVE SANDSTONE. THE VOLCANIC UNIT AND LOWER PART OF THE SEDIMENTARY SUCCESSION CONTAIN THE SULPHIDE MINERALIZATION.

TO THE WEST OF THE FAULT SANDSTONE AND QUARTZITE OF THE WESTERN SEQUENCE CROP OUT.

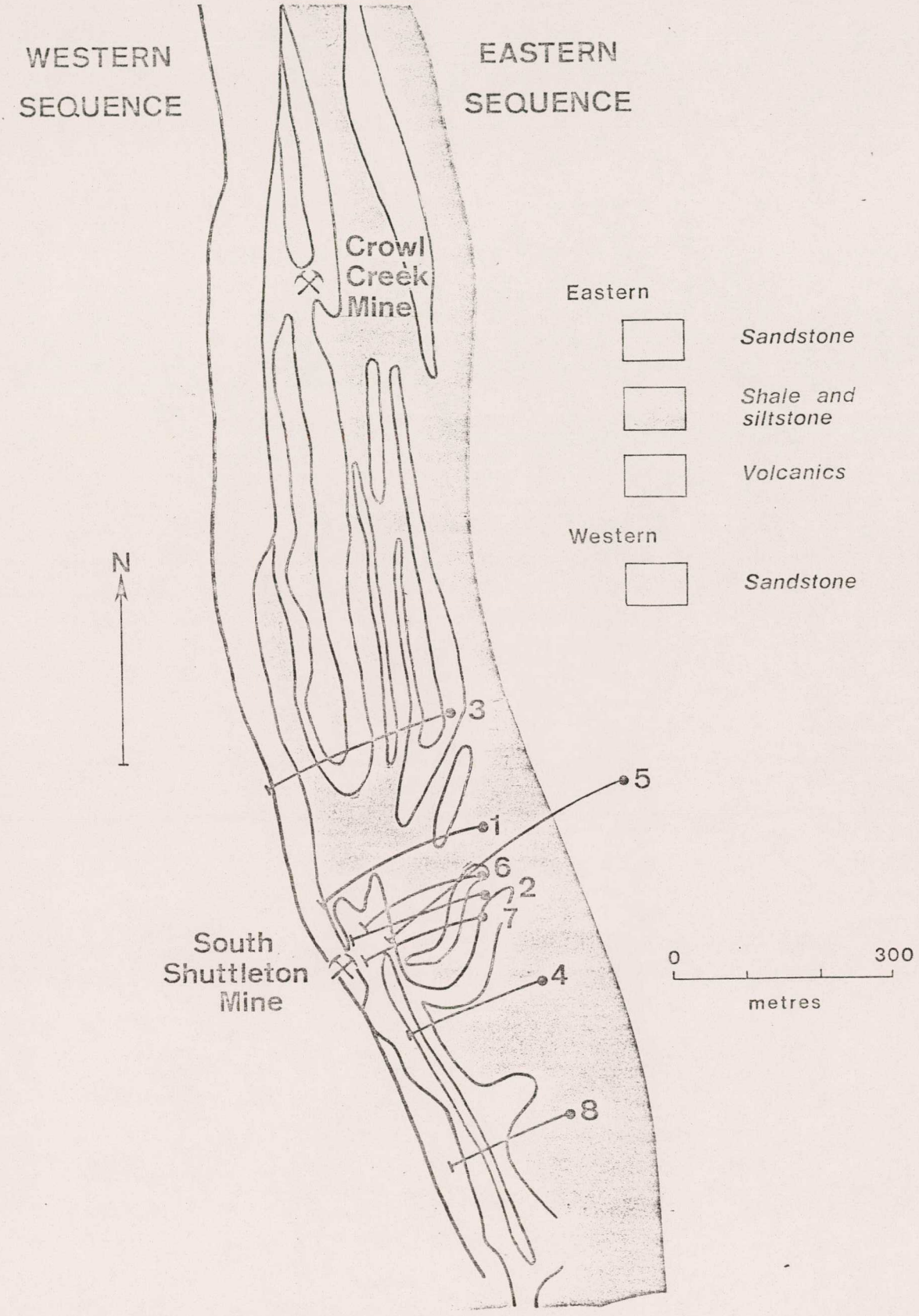
SLIDE 5 (PRINT)

MOST INFORMATION ABOUT THE RELATIONSHIP BETWEEN MINERALIZATION AND STRATIGRAPHY COMES FROM DRILLING IN THE SOUTH SHUTTLETON AREA WHERE A NUMBER OF DIAMOND DRILL HOLES HAVE TESTED THE VOLCANIC UNIT ADJACENT TO THE FAULT AND THE IMMEDIATELY OVERLYING SEDIMENTS. THIS DRILLING HAS BEEN DESCRIBED IN DETAIL IN REPORTS BY SWISS ALUMINIUM ASTRALIA PTY LTD AND WE ACKNOWLEDGE THE USE OF THIS DATA.

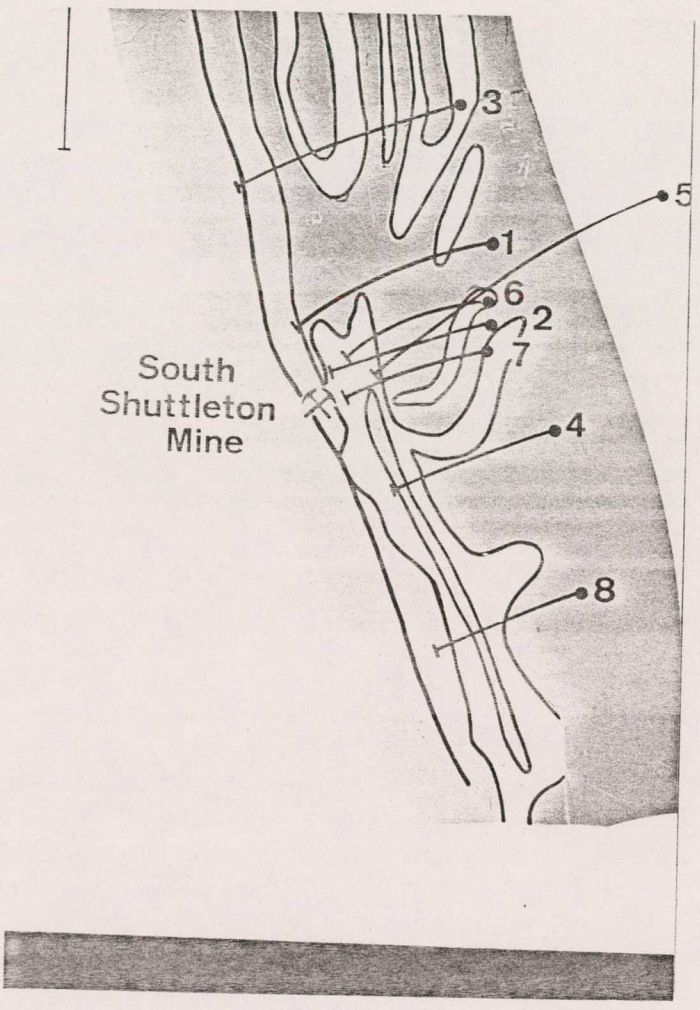


SLIDE 4 (PRINT)

SHUTTLETON GEOLOGY



SLIDE 4 (PLAN)



SLIDE 5 (PRINT)

ALTHOUGH OUTCROP IS GOOD, DETERMINATION OF BEDDING DIPS IS DIFFICULT AND THEREFORE THE STRUCTURAL SETTING REMAINS OBSCURE. THE VOLCANICS AND SEDIMENTS EAST OF THE MAJOR FAULT PROBABLY FORM A GENERALLY EASTERLY DIPPING AND FACING SEQUENCE WHICH IN THE SOUTH SHUTTLETON AREA IS FOLDED INTO A SHALLOWLY SOUTH PLUNGING ANTICLINE.

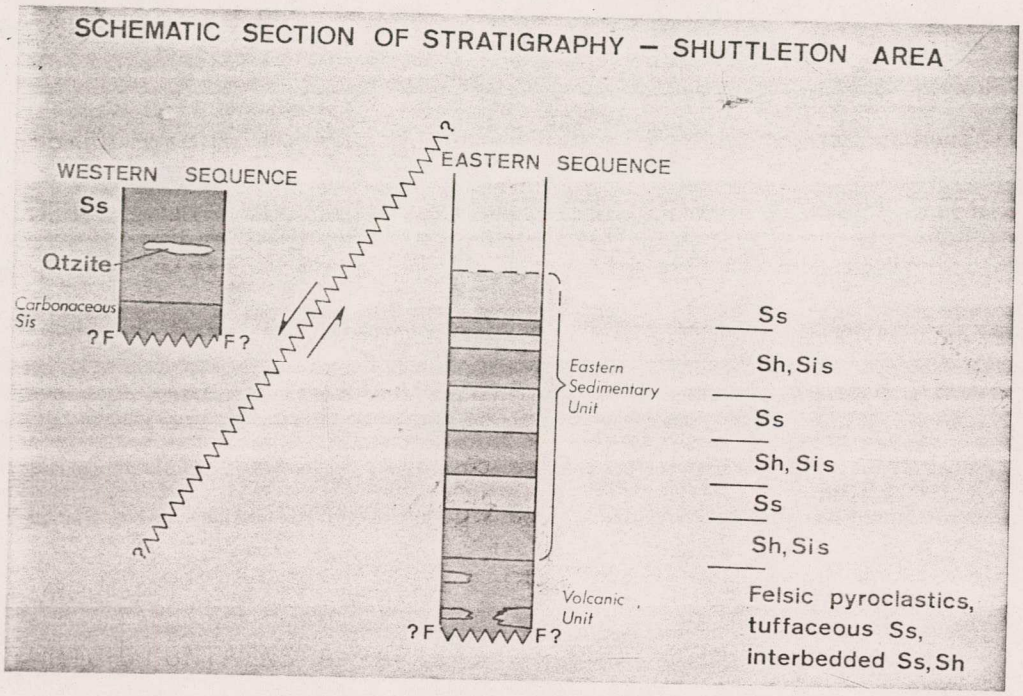
SLIDE 6 (PRINT)
SLIDE 6 (PLAN)

THE STRATIGRAPHY IN THE SOUTH SHUTTLETON AREA IS SHOWN IN MORE DETAIL ON THIS SLIDE. DRILLING REVEALS THE WESTERN SEQUENCE CONTAINS SILTSTONE, WHICH IN PART IS WEAKLY CARBONACEOUS, IN ADDITION TO THE SANDSTONE AND QUARTZITE SEEN IN OUTCROP. THIS IS SEPARATED BY THE FAULT FROM THE EASTERN SEQUENCE.

THE LOWERMOST UNIT OF THE EASTERN SEQUENCE IS THE VOLCANIC UNIT WHICH CONTAINS A VARIETY OF ROCK TYPES:

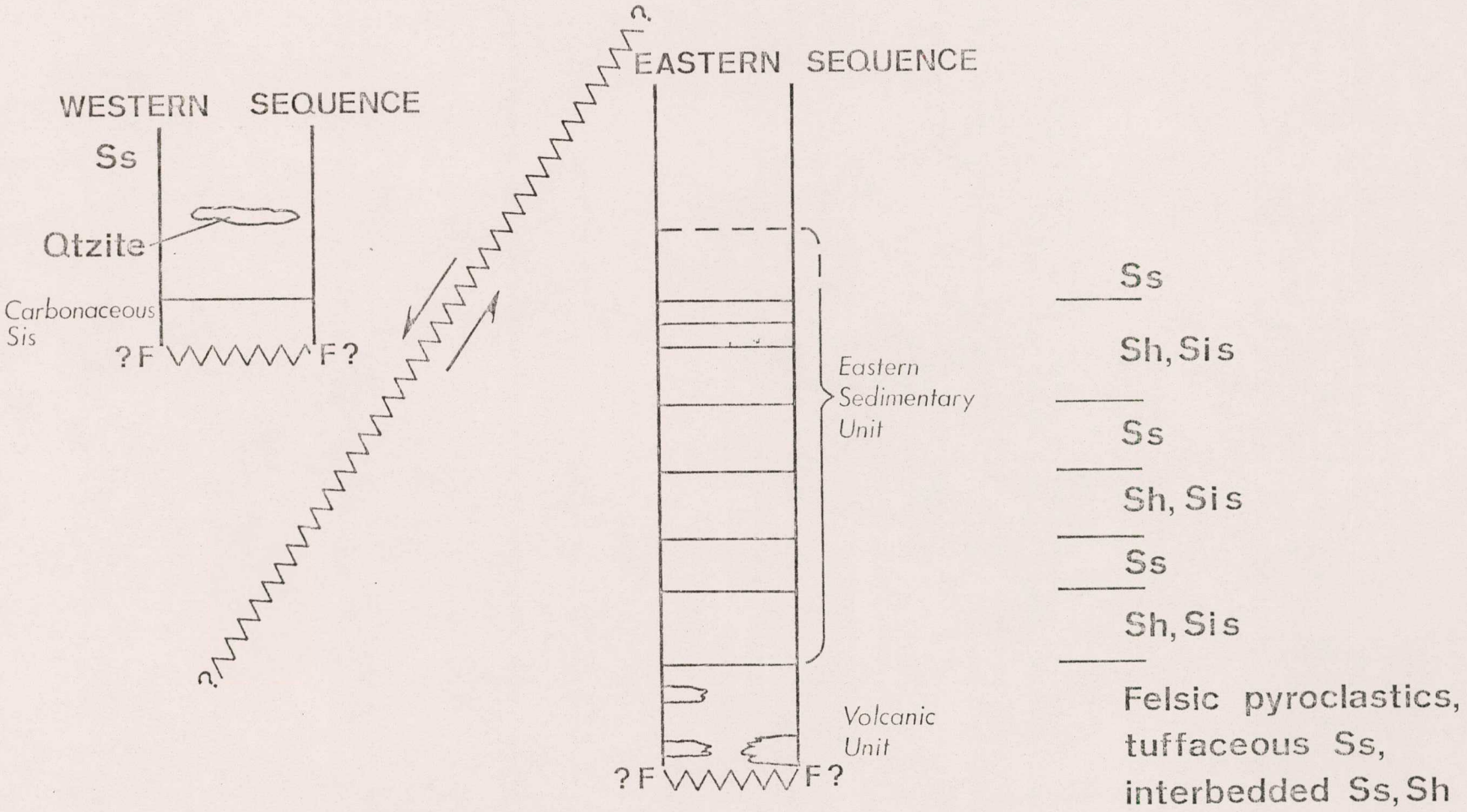
I) CRYSTAL LITHIC TUFFS OF RHYOLITIC TO RHYODACITIC COMPOSITION,
II) VOLCANICLASTIC SEDIMENTS - MAINLY LITHIC TUFFS AND LITHIC SANDSTONE - AND
III) SANDSTONE AND CHLORITIC SHALE AND SILTSTONE SIMILAR TO THAT IN THE OVERLYING SEDIMENTARY ROCKS SHOWN AS THE EASTERN SEDIMENTARY UNIT.

THE EASTERN SEDIMENTARY UNIT CONSISTS OF SANDSTONE INTERBEDDED WITH SILTSTONE AND SHALE.



SLIDE 6 (PRINT)

SCHEMATIC SECTION OF STRATIGRAPHY – SHUTTLETON AREA



SLIDE 6 (PLAN)

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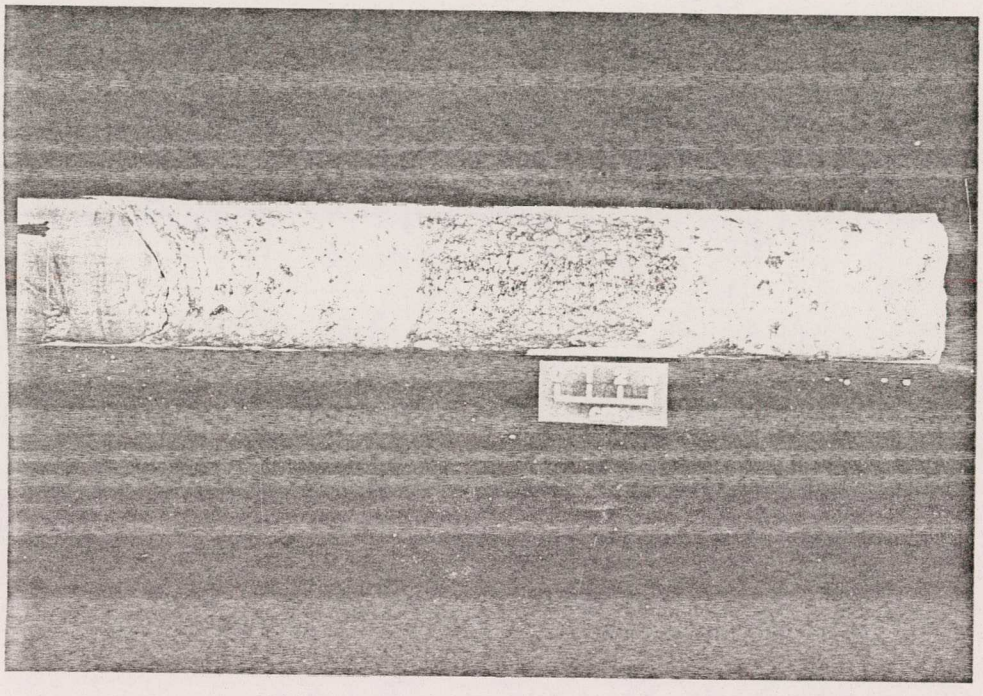
SLIDE 7 (PRINT)

AN EXAMPLE OF THE HETEROGENEITY OF THE VOLCANIC UNIT IS SHOWN IN THIS SLIDE OF DRILL CORE. THERE IS A DARK ROUNDED CLAST OF CRYSTAL TUFF IN THE CENTRAL PART OF THE CORE IN A MATRIX OF LITHIC SANDSTONE TOGETHER WITH IRREGULAR CLASTS OF SILTSTONE.



SLIDE 7 (PRINT)

Heterogeneous rock, Volcanic Unit. Clasts of crystal tuff and siltstone in a matrix of lithic sandstone. Drill core, DDH 1 (SHID) 348.4-348.7 m

MINERALIZATION

SLIDE 8 (PRINT)
SLIDE 8 (PLAN)

THIS SLIDE SHOWS THE SEQUENCE OF ROCKS INTERSECTED IN DIAMOND DRILLING AT SOUTH SHUTTLETON. IT IS A PLAN IN THE PLANE OF THE DRILL HOLES, WITH "DIAGRAMMATIC" CORRELATIONS - UNFORTUNATELY THERE ARE NO MARKER HORIZONS IN THE SEDIMENTARY ROCKS TO THE EAST OF, AND THEREFORE PROBABLY STRATIGRAPHICALLY ABOVE, THE VOLCANIC UNIT.

THE SIGNIFICANT COPPER INTERSECTIONS IN THE DRILL HOLES ARE SHOWN. THEY OCCUR IN THE VOLCANIC UNIT AND IMMEDIATELY OVERLYING SEDIMENTS TO THE EAST.

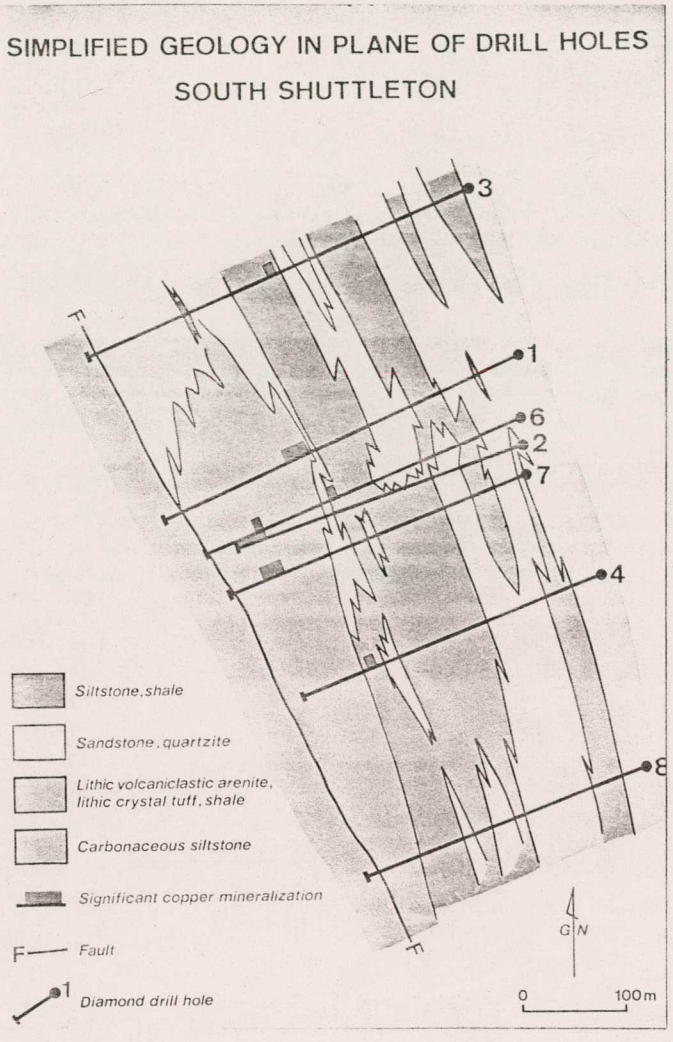
THERE IS NO MINERALIZATION IN THE WEAKLY CARBONACEOUS SEDIMENTS TO THE WEST OF THE FAULT.

SLIDE 9 (PRINT)
SLIDE 9 (PLAN)

THE DOMINANT SULPHIDES AT SOUTH SHUTTLETON ARE PYRITE, PYRRHOTITE AND CHALCOPYRITE. SPHALERITE AND GALENA ARE FAR LESS COMMON.

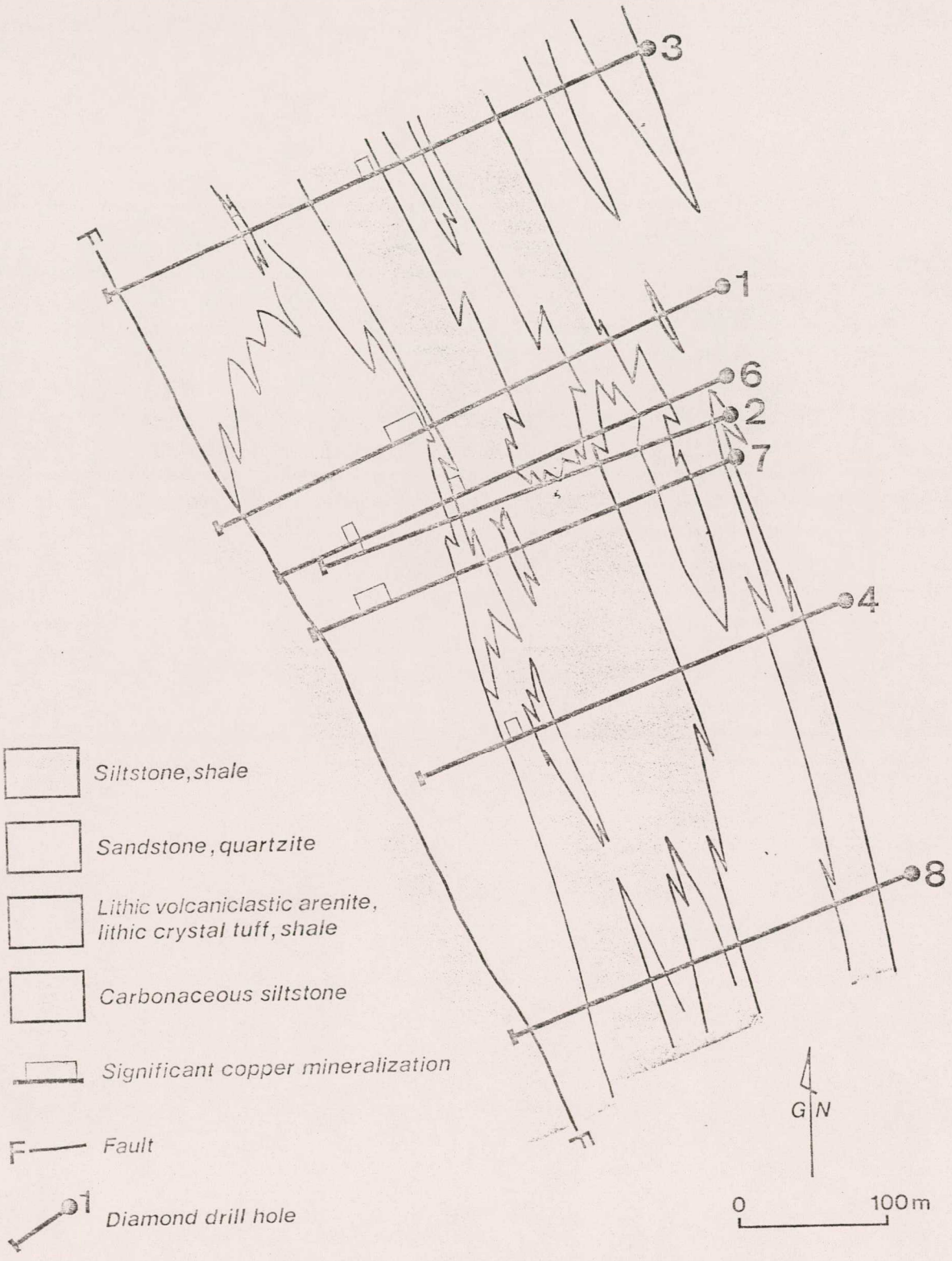
THE STRONGEST COPPER MINERALIZATION OCCURS IN THE VOLCANIC UNIT.

THERE IS A SEPARATION OF PYRITE AND PYRRHOTITE. PYRITE IS ABUNDANT THROUGHOUT THE VOLCANIC UNIT AND IMMEDIATELY OVERLYING SHALES WHEREAS PYRRHOTITE IS MORE COMMON NEAR THE TOP OF THAT STRATIGRAPHIC INTERVAL AND IN MOST HOLES EXTENDS FURTHER INTO THE OVERLYING SEDIMENTS.

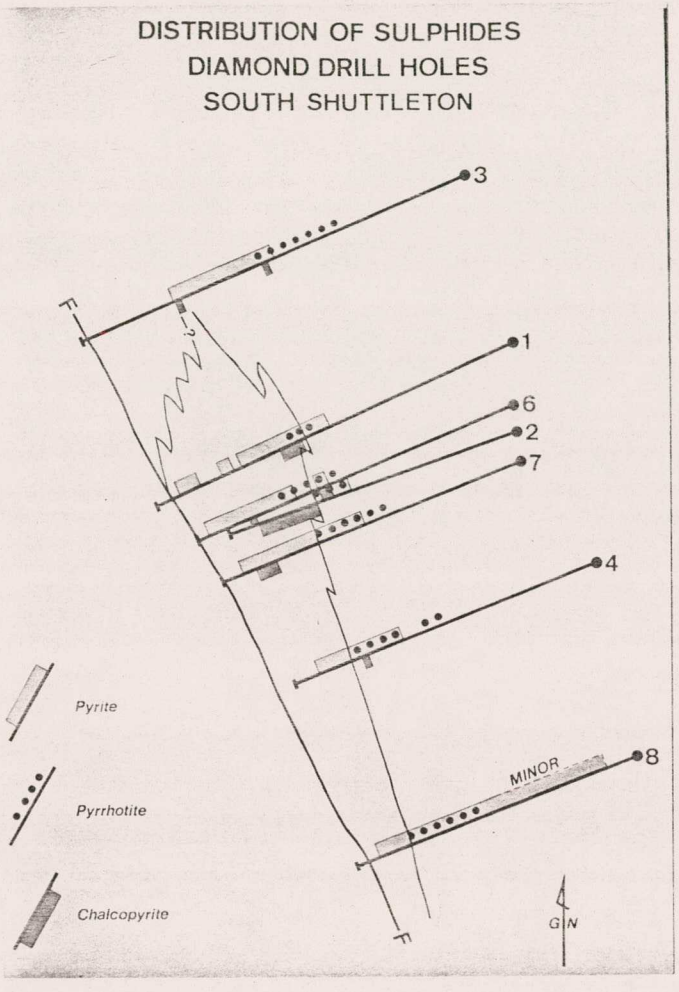


SLIDE 8 (PRINT)

SIMPLIFIED GEOLOGY IN PLANE OF DRILL HOLES
SOUTH SHUTTLETON

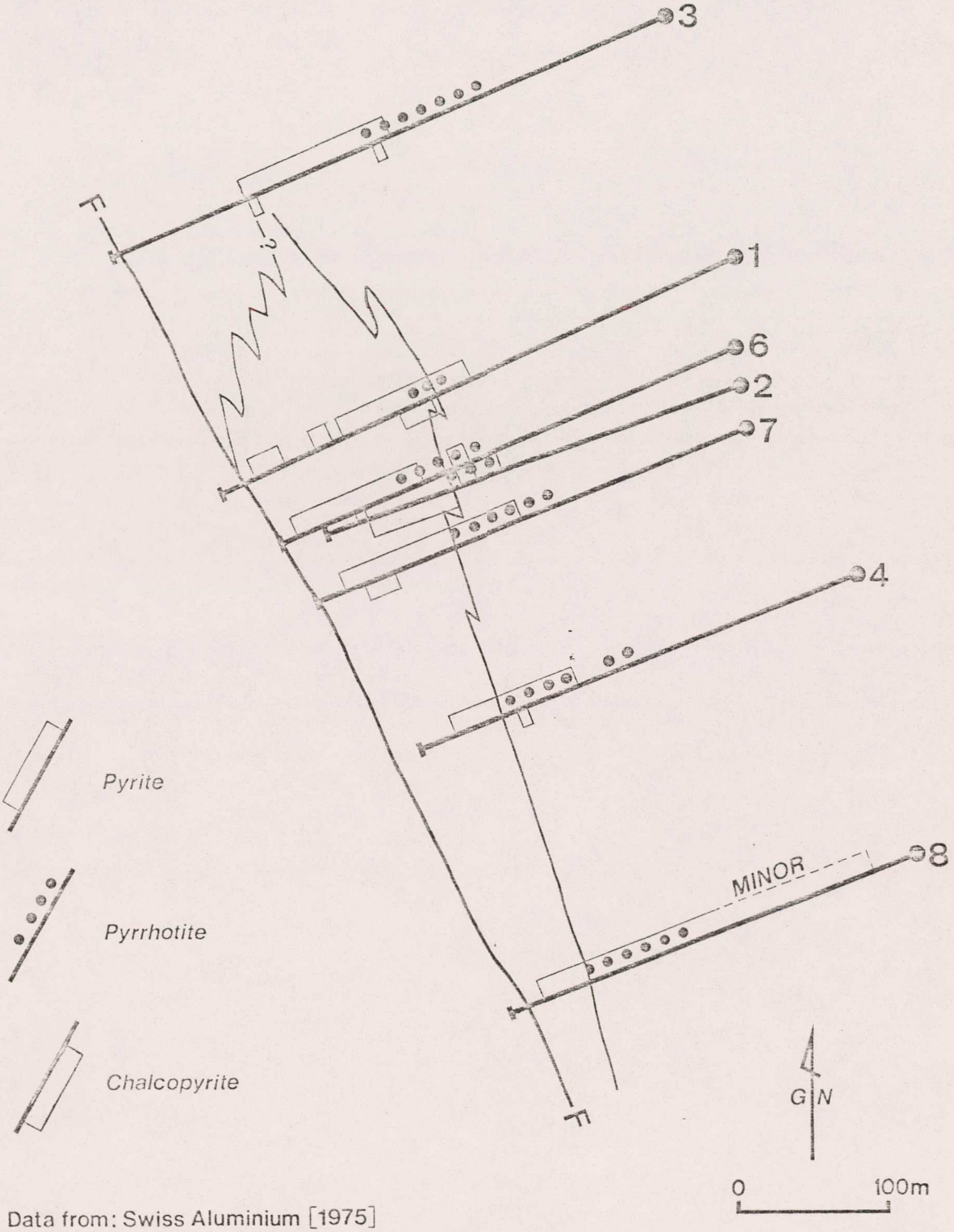


SLIDE 8 (PLAN)



SLIDE 9 (PRINT)

DISTRIBUTION OF SULPHIDES
DIAMOND DRILL HOLES
SOUTH SHUTTLETON



Data from: Swiss Aluminium [1975]

SLIDE 9 (PLAN)

THE SULPHIDES OCCUR IN A VARIETY OF TEXTURAL ASSOCIATIONS INCLUDING MASSIVE BANDS, DISSEMINATIONS, STOCKWORK VEINS AND BRECCIA FILL. THERE IS ABUNDANT EVIDENCE THAT THE SULPHIDES HAVE BEEN DEFORMED, AS WE SHALL SEE.

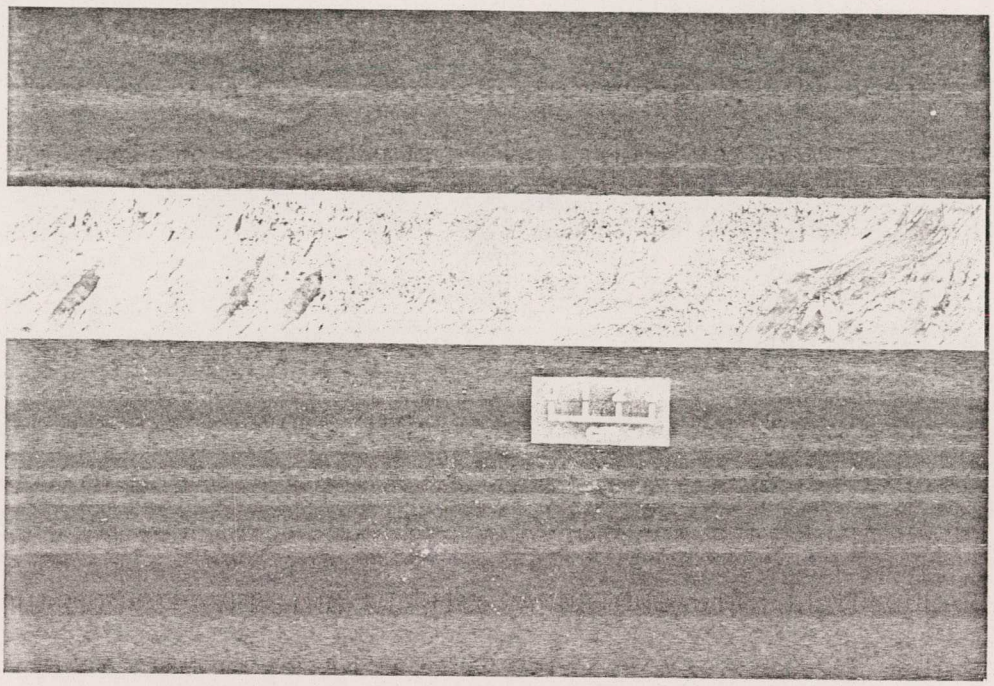
SULPHIDES OCCUR THROUGHOUT THE VOLCANIC UNIT. CHALCOPYRITE IS DEVELOPED AT SEVERAL LEVELS AND IS USUALLY ASSOCIATED WITH PYRITE, ALTHOUGH PYRITE IS FAR MORE WIDESPREAD. PYRRHOTITE OCCURS NEAR THE TOP OF THE UNIT. THE STRONGEST MINERALIZATION IN THE VOLCANIC UNIT OCCURS WITHIN BLACK CHLORITIC SHALE.

S L I D E 10 (PRINT)

BUT THE REMAINDER OF THE VOLCANIC UNIT IS BY NO MEANS BARREN, AND THIS SLIDE SHOWS VEINS OF PYRITE AND CHALCOPYRITE, WITH AND WITHOUT QUARTZ, TRAVERSING LITHIC SANDSTONE WITH LENTICULAR CLASTS OF CLAYSTONE AND CLAYSTONE BANDS.

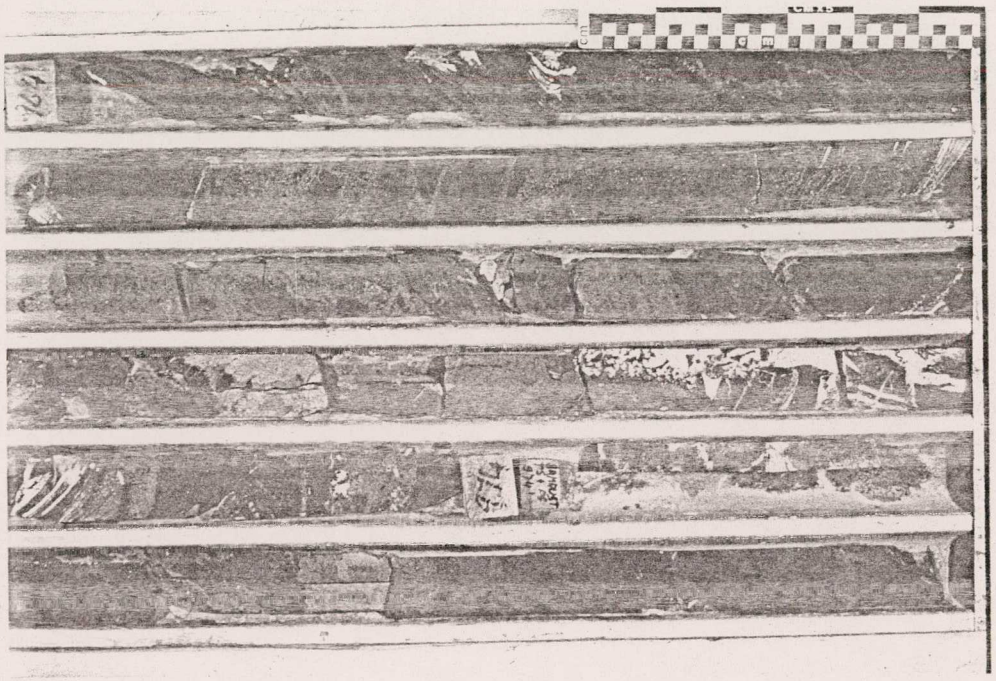
S L I D E 11 (PRINT)

THIS SLIDE SHOWS A TRAY OF CORE FROM THE MOST STRONGLY MINERALIZED INTERSECTION MADE IN DRILLING AT SOUTH SHUTTLETON - DRILL ROD LENGTH OF 16.8 M AVERAGING 3.05% COPPER, .64% LEAD AND .5% ZINC. THE MAIN HOST ROCK IS A BLACK CHLORITIC SHALE. THERE ARE A VARIETY OF TEXTURES DEVELOPED AND WE WILL LOOK AT SLIDES OF CORE FROM THREE PLACES IN THE CORE TRAY, (SLIDES 12 TO 15).



SLIDE 10 (PRINT)

Lithic sandstone with clasts and irregular bands of claystone and veins of pyrite and chalcopyrite Volcanic Unit. Drill core, DDH 1 (SHID) 287.2-287.6 m.



SLIDE 11 (PRINT)

Strong chalcopyrite and pyrite in black chloritic shale. Volcanic Unit. Drill core, DDH 2 (37S-2D) 293.8-297.9 m.

SLIDE 12 (PRINT)

THIS SLIDE SHOWS A FOLDED VEIN OR BAND OF CHALCOPYRITE-PYRITE IN BLACK CHLORITIC SHALE IN THE RIGHT HALF OF THE CORE AND TIGHTLY FOLDED BANDS OF FINE AND COARSE GRANULAR PYRITE IN SHALE IN THE LEFT HALF.

SLIDE 13 (PRINT)

THIS SLIDE IS A CLOSE UP OF THE FOLDED BAND OR BED OF GRANULAR PYRITE. LENSES OF FINE PYRITE GRAINS ARE FLATTENED AND ALIGNED IN CLEAVAGE.

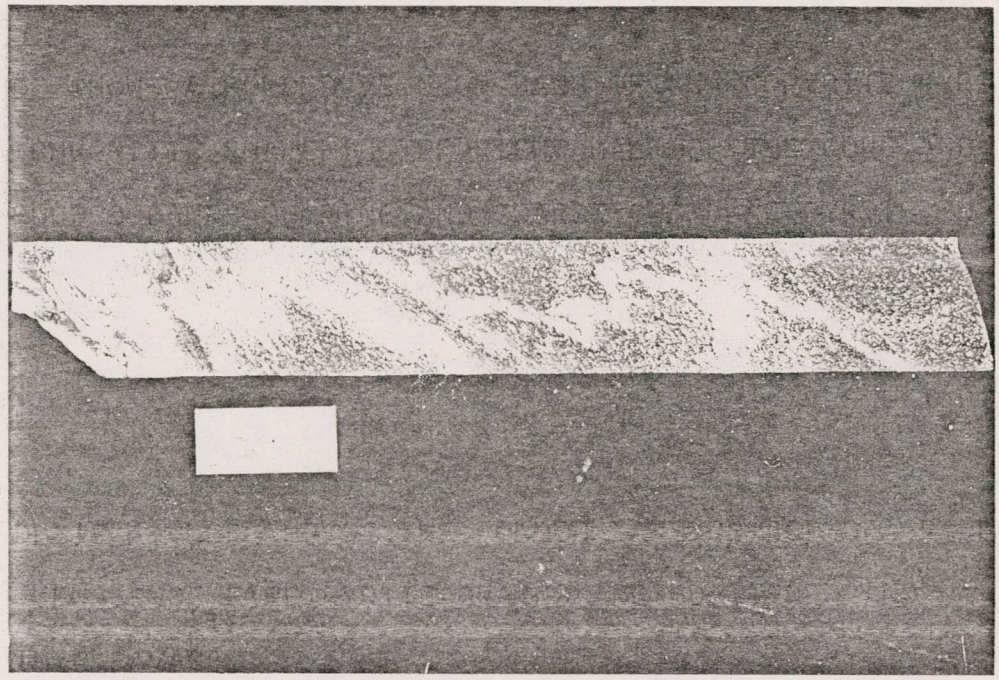
SLIDE 14 (PRINT)

STRONG CHALCOPYRITE MINERALIZATION HAS A FOLIATION DIAGONALLY FROM LEFT TO RIGHT IN THIS SLIDE. THIS IS A DUCTILE FLOW FOLIATION AND RELATIONSHIP TO CLEAVAGE IS NOT KNOWN.

SLIDE 15 (PRINT)

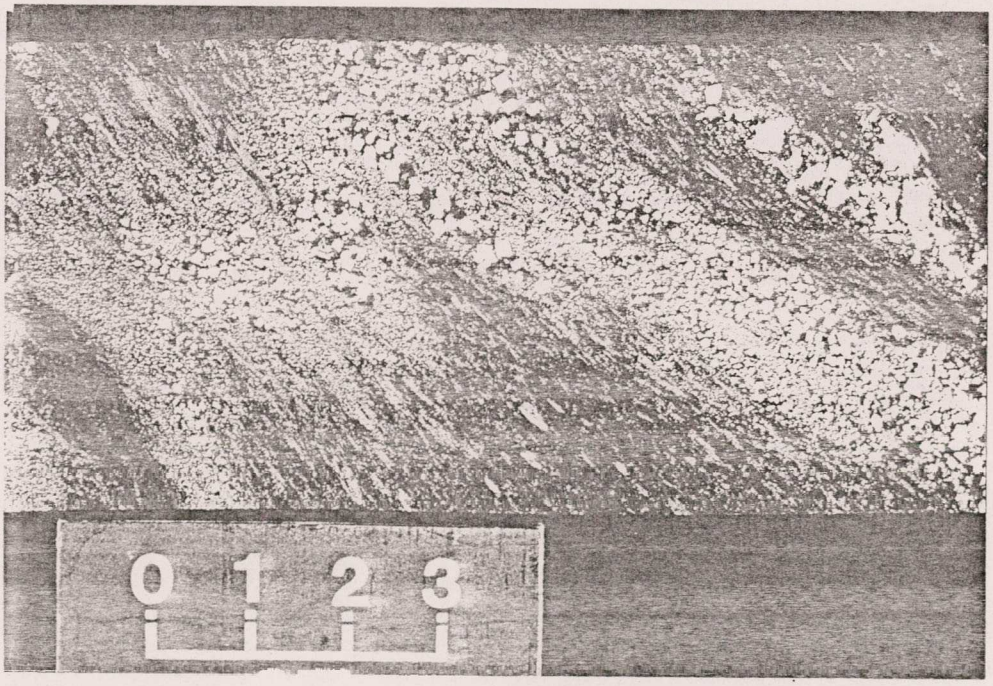
THIS SLIDE FROM NEARBY SHOWS CHALCOPYRITE-PYRITE MINERALIZATION IN CONTACT WITH FOLDED BLACK CHLORITIC CLAYSTONE AND PYRITIC SILTSTONE. DEFORMATION HAS CAUSED THE DUCTILE CHALCOPYRITE TO FILL THE CRACKS IN THE BLACK CLAYSTONE WHICH FORMED BECAUSE OF THE CLAYSTONE'S BRITTLE BEHAVIOUR DURING DEFORMATION.

NOTE THAT NO CLEAVAGE IS FORMED, IN CONTRAST TO THE PREVIOUS SLIDES. THIS MAY BE DUE TO THE FACT THAT DUCTILE MASSIVE SULPHIDES HAVE ACCOMMODATED THE STRAIN DURING THE DEFORMATION THAT RESULTED IN CLEAVAGE IN FINE GRAINED SEDIMENTS ELSEWHERE.



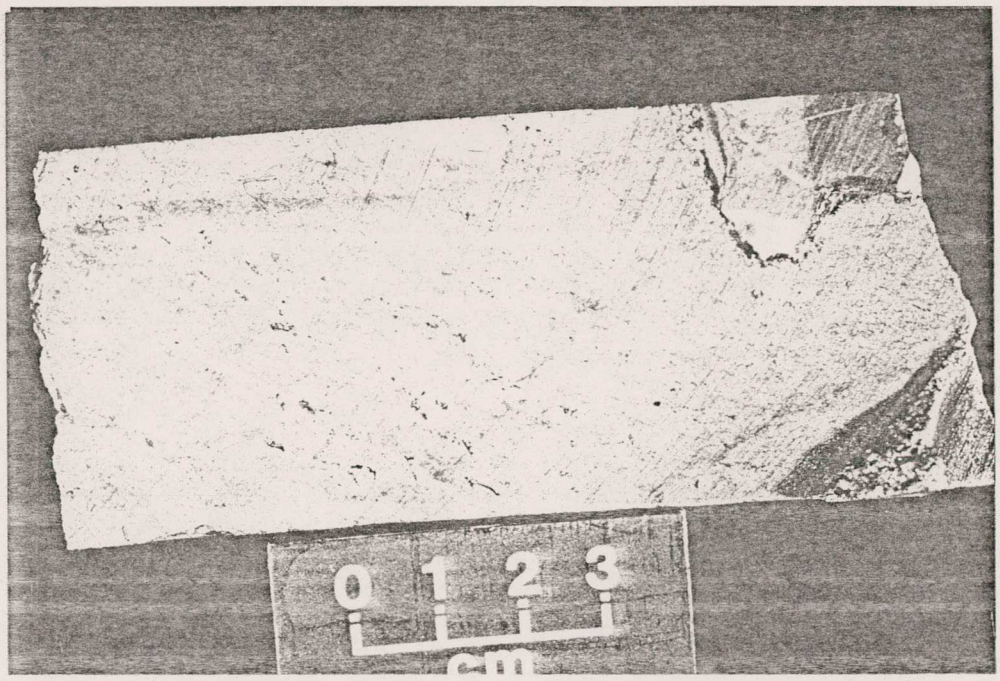
SLIDE 12 (PRINT)

Black chloritic shale with folded vein or band of chalcopyrite-pyrite (right half of slide) and folded layer of fine and coarse granular pyrite (left half). Drill core, DDH 2 (37S-2D) 294.13-294.49 m.



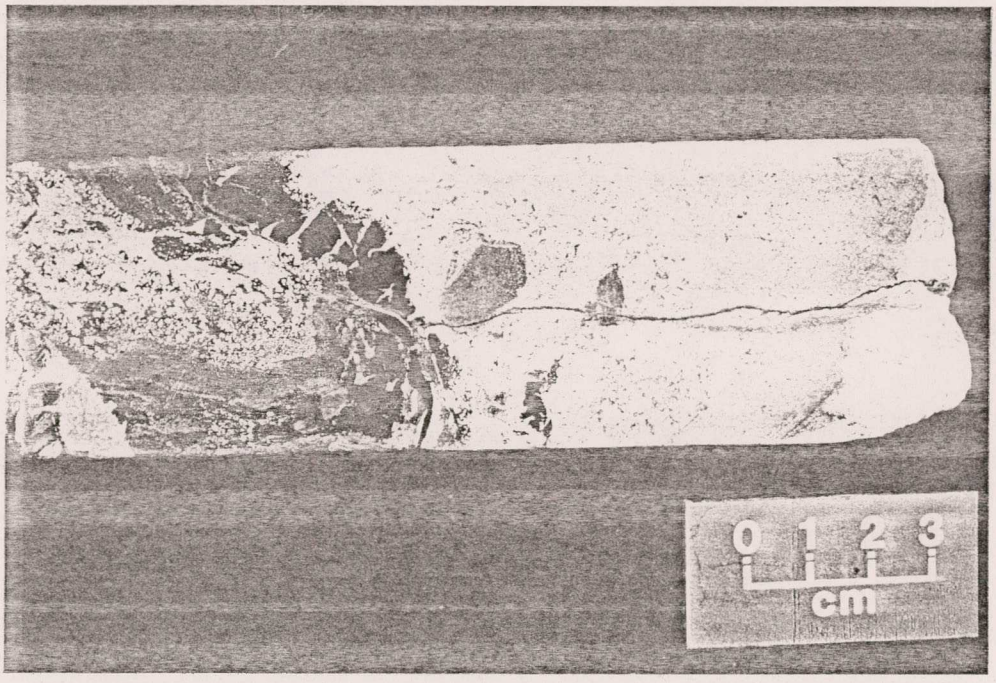
SLIDE 13 (PRINT)

Folded layer of granular pyrite in chloritic shale (see slide 12). Lenses of fine grained pyrite flattened and aligned in cleavage. Drill core DDH 2 (37S-2D) 294.3 m.



SLIDE 14 (PRINT)

Strong chalcopyrite mineralization showing foliation (top left to bottom right). Drill core DDH2 (37S-2D) 296.17 m.



SLIDE 15 (PRINT)

Chalcopyrite-pyrite mineralization in contact with folded black chloritic siltstone and pyritic siltstone. Drill core DDH2 (37S-2D) 296.0 m.

SLIDE 16 (PRINT)

HERE WE HAVE CHALCOPYRITE RICH MINERALIZATION IN BLACK CHLORITIC SILTSTONE. THE SILTSTONE HAS BEEN BRECCIATED AND PARTLY INCORPORATED IN THE MASSIVE SULPHIDE TO GIVE A TEXTURE OF THE DURCHBEWEGUNG TYPE. THE LIGHTER COLOURED AREA ON THE LEFT HAND SIDE OF THE SPECIMEN IS PYRITE RICH MINERALIZATION.

SLIDE 17 (PRINT)

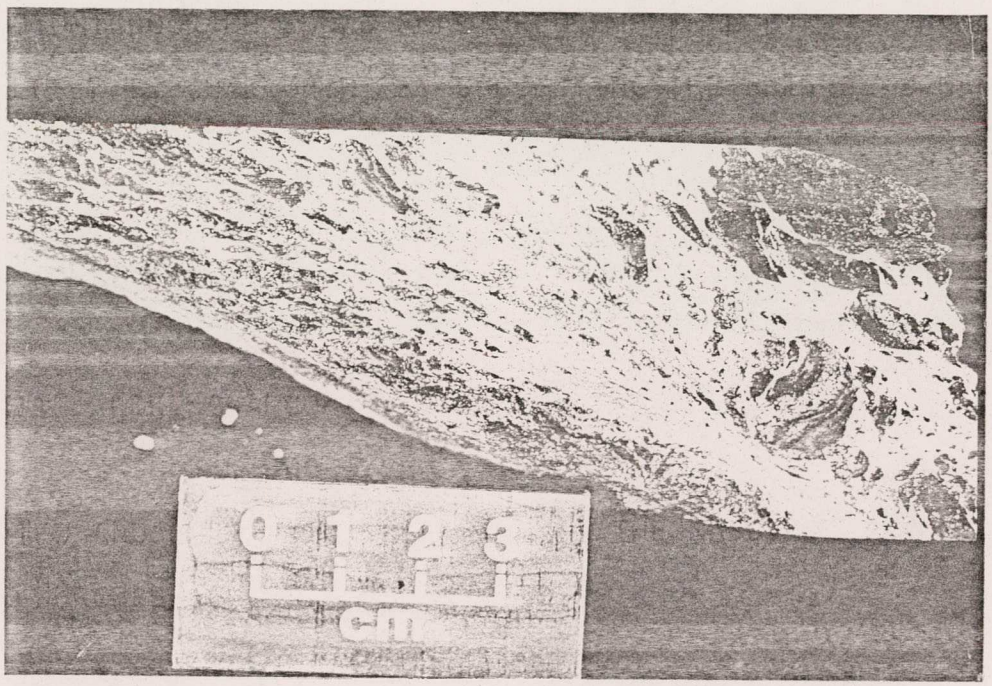
THIS PHOTOMICROGRAPH SHOWS FRACTURED EUHEDRAL PYRITE INVADED AND ENCLOSED BY CHALCOPYRITE, SUGGESTING THE BRITTLE BEHAVIOUR OF PYRITE DURING DEFORMATION.

SLIDE 18 (PRINT)

PYRRHOTITE, LIKE CHALCOPYRITE, HAS UNDERGONE DUCTILE DEFORMATION AND THE LESS DUCTILE HOST SHALES AND SILTSTONES HAVE BEEN BRECCIATED AND PARTLY INCORPORATED IN THE MASSIVE SULPHIDES TO GIVE DURCHBEWEGUNG TYPE TEXTURES.

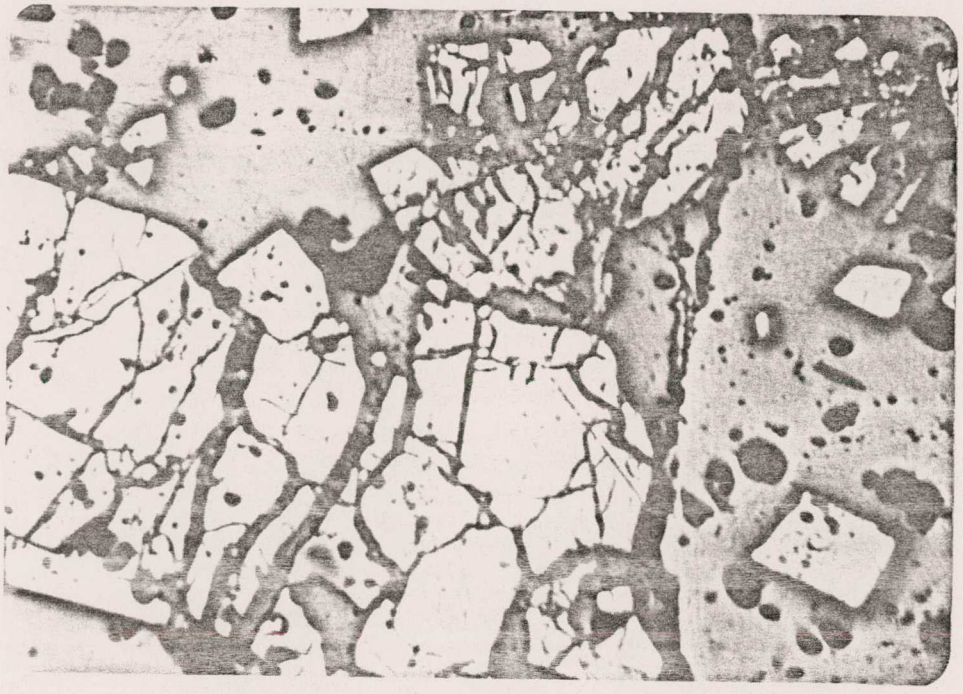
SLIDE 19 (PRINT)

SOME TEXTURES ARE DIFFICULT TO INTERPRET, SUCH AS THIS IRREGULAR MASS OF PYRRHOTITE AND QUARTZ IN SERICITIC CLAYSTONE AND SILTSTONE WITH MINOR CHLORITE VEINLETS. DUCTILE DEFORMATION MAY HAVE RESULTED IN THE INJECTION OF THE PYRRHOTITE MASS INTO THE CLAYSTONE, BUT THE PRESENCE OF QUARTZ ON THE MARGINS OF THE PYRRHOTITIC BODY COULD INDICATE THAT DEPOSITION OCCURRED FROM METAHYDROTHERMAL SOLUTIONS.



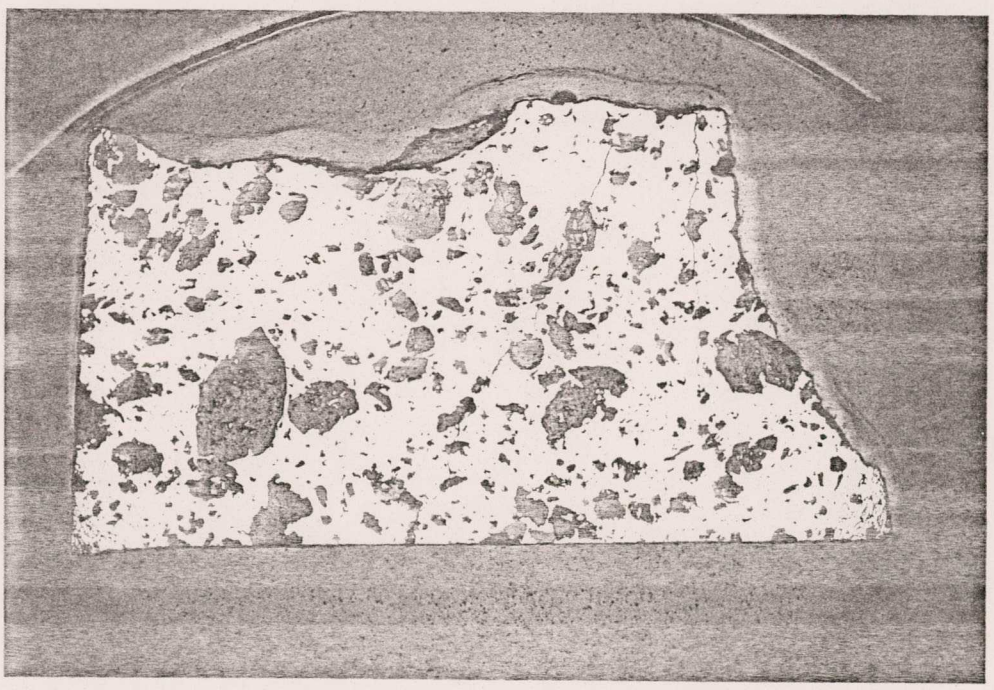
SLIDE 16 (PRINT)

Chalcopyrite rich mineralization (yellow), with lighter coloured pyritic band diagonally top left to bottom right, in black chloritic siltstone. Siltstone is brecciated and partly incorporated in massive sulphide to give Durchbewegung type texture. Drill core DDH 2 (37S-2D) 299.67 m.



SLIDE 17 (PRINT)

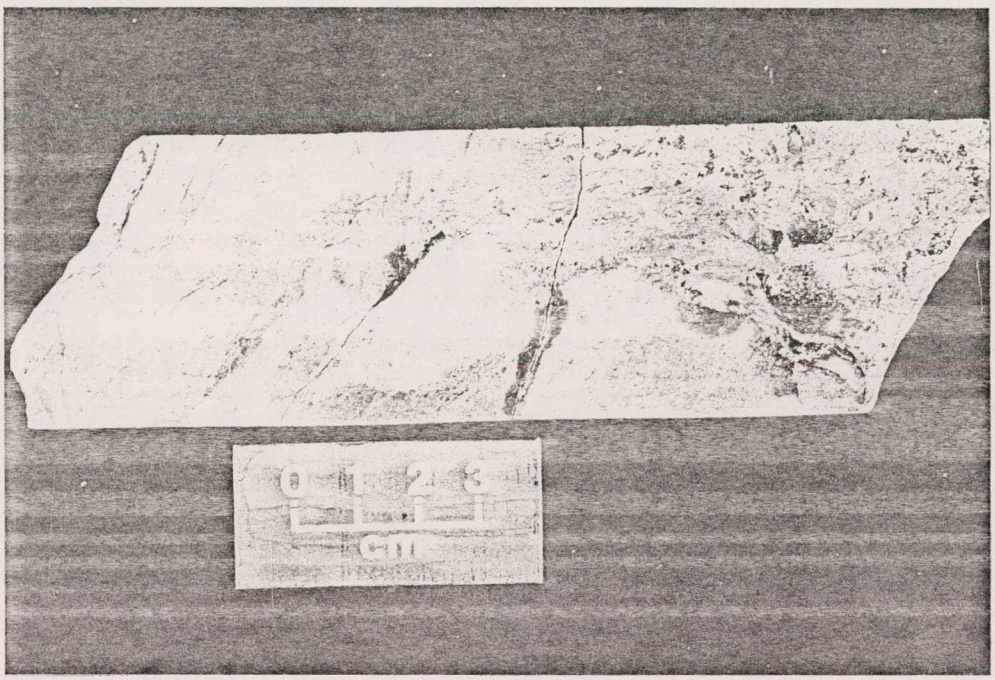
Photomicrograph, fractured euhedral pyrite in chalcopyrite. Polished Section P 652; drill core DDH 4 (37S-4D) 302.51 m. (X90)



10 mm

SLIDE 18 (PRINT)

Pyrrhotite enclosing shale and siltstone, Durchbewegung type texture. Polished Section P 951; drill core DDH 6 (SHD-6) 286.2 m.



SLIDE 19 (PRINT)

Irregular mass of pyrrhotite and quartz in sericitic claystone and siltstone. Minor chlorite veinlets. Drill core DDH 6 (SHD-6) 280.2 - 280.5 m.

THESE TEXTURES INDICATE THAT MINERALIZATION HAS BEEN DEFORMED. PYRITE WAS BRITTLE WHEREAS PYRRHOTITE AND CHALCOPYRITE WERE DUCTILE.

THE OCCURRENCE OF MASSIVE PYRRHOTITE IN THICK VEINS WITH AND WITHOUT CHLORITE AND QUARTZ COULD INDICATE THAT FLUID STATE REMOBILIZATION HAS OCCURRED.

HOWEVER IN PLACES THE VEIN TYPE PYRRHOTITE MINERALIZATION ALSO APPEARS TO HAVE UNDERGONE DUCTILE DEFORMATION WITH INCORPORATION OF FRAGMENTS OF WALL ROCK - SUGGESTING POST-FRACTURE MOVEMENT. THERE PROBABLY HAS BEEN A COMPLEX INTERPLAY OF FLUID - DOMINATED REMOBILIZATION AND DUCTILE DEFORMATION.

CHLORITE

THE DISTRIBUTION AND OCCURRENCE OF CHLORITE COULD SHED SOME LIGHT ON THE QUESTION OF REMOBILIZATION OF MINERALIZATION AT SHUTTLETON.

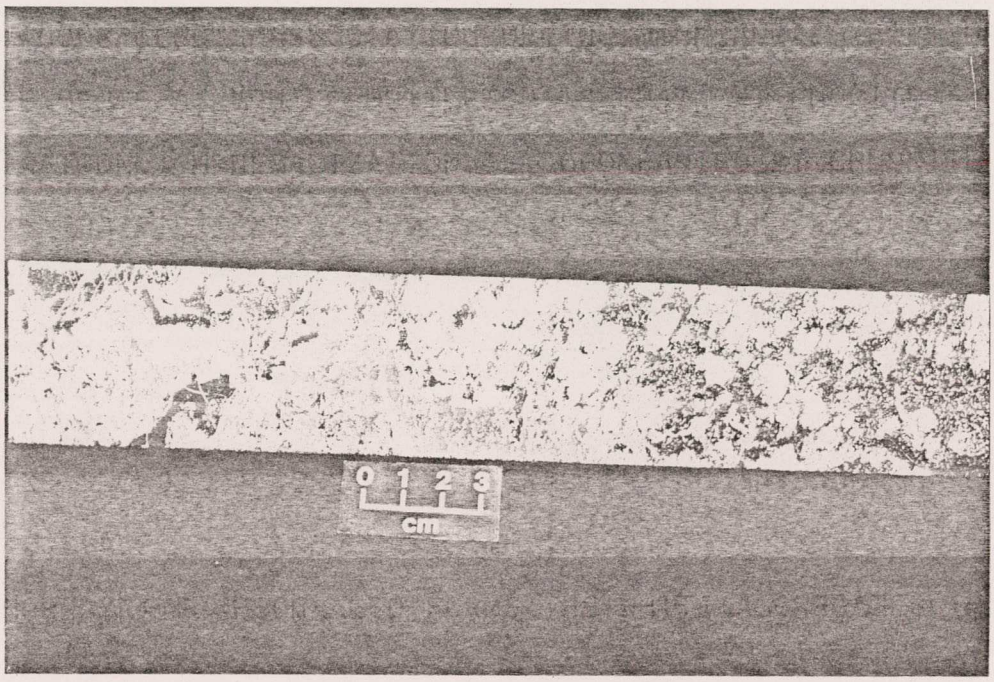
THE MOST CONSPICUOUS ASSOCIATION OF THE MINERALIZED PORTION OF THE SEQUENCE AT SOUTH SHUTTLETON IS THAT OF CHLORITE AND MINERALIZATION. MINERALIZATION IS ACCOMPANIED BY CHLORITE AND TO A LESSER EXTENT BY QUARTZ, CARBONATE AND TALC.

SLIDE 20 (PRINT

THIS SLIDE SHOWS CHALCOPYRITE MINERALIZATION IN BLACK CHLORITIC SHALE. THE CHALCOPYRITE IS BORDERED BY CALCITE WITH MINOR PYRITE WHICH ALSO FORMS THE WHITE AGGREGATES IN THE BLACK SHALE.

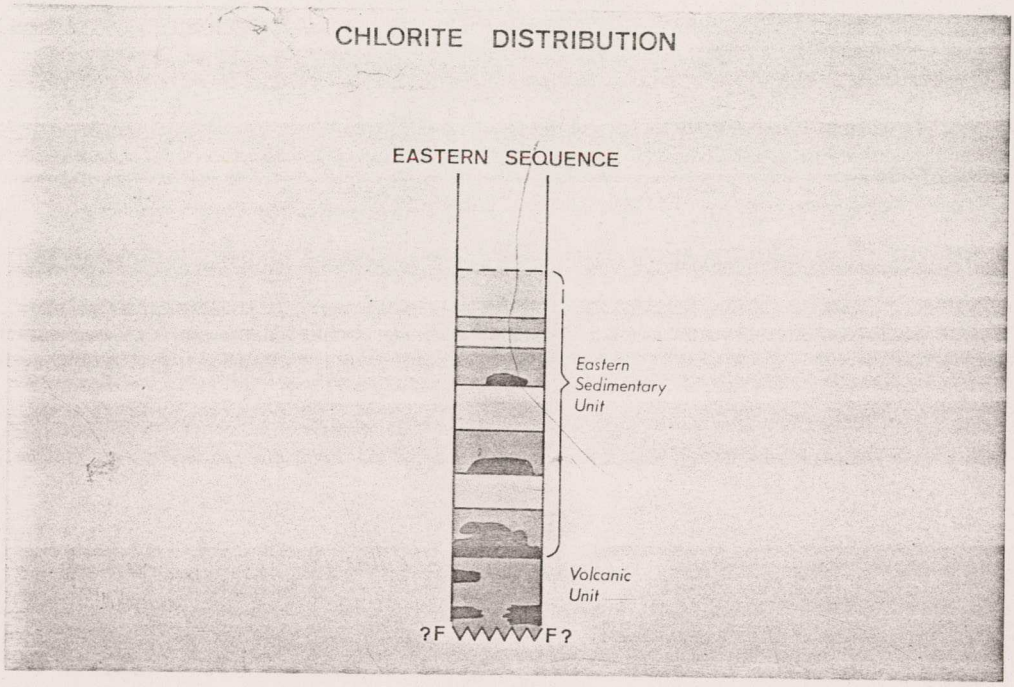
SLIDE 21 (PRINT)
SLIDE 22 (PLAN)

CHLORITE IS MOST ABUNDANT IN THE MINERALIZED SECTIONS OF THE VOLCANIC UNIT, ESPECIALLY IN THE FINE GRAINED SEDIMENTS AND ALSO IS MOST STRONGLY DEVELOPED IN THE LOWERMOST SECTIONS OF THE OVERLYING SHALE UNITS. THE CHLORITE CONTENT OF THE SHALE UNITS DECREASES UPWARDS AND THE CHLORITE CONTENT OF EACH SHALE UNIT, GENERALLY SPEAKING, IS GREATEST NEAR ITS BASE.



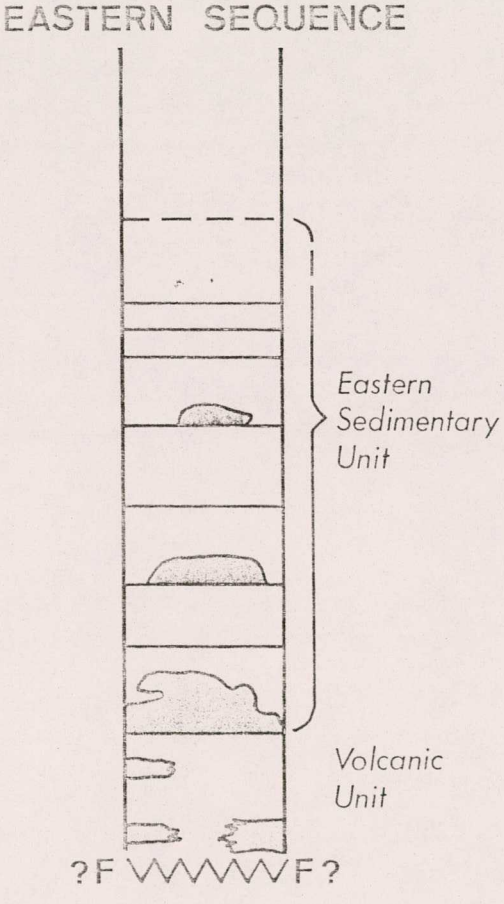
SLIDE 20 (PRINT)

Black chloritic siltstone with strong chalcopyrite mineralization. Chalcopyrite bordered by calcite (white). Calcite also forms white aggregates in siltstone. Drill core DDH 2 (37S-2D) 289.56-289.86 m.



SLIDE 21 (PRINT)

CHLORITE DISTRIBUTION



SLIDE 21 (PLAN)

WE HAVE ALREADY SEEN SEVERAL SLIDES OF THE STRONGLY CHLORITIC SHALE WHICH CONTAINS THE RICH CHALCOPYRITE-PYRITE MINERALIZATION IN THE VOLCANIC UNIT.

SLIDE 22 (PRINT

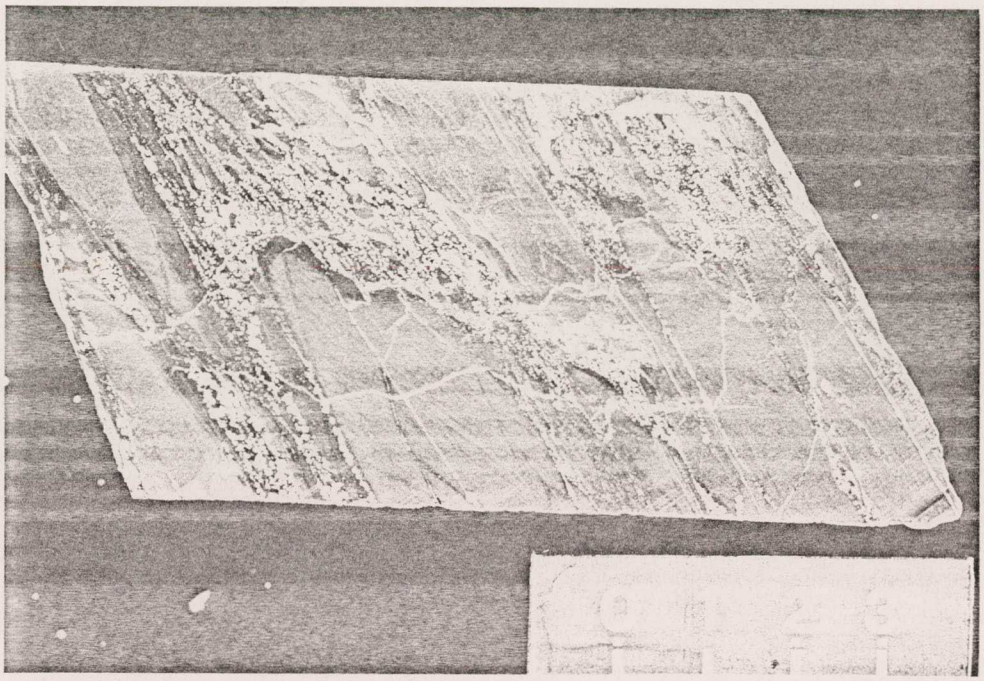
CHLORITE ALTERATION IN SHALE IS DISTINCTIVE. AWAY FROM SECTIONS WHERE STRONG CHLORITE IS UNIFORMLY DEVELOPED IN THE EASTERN SEDIMENTARY UNIT, DARK VEINLIKE CHLORITIC MASSES TRAVERSE LIGHTER COLOURED SERICITIC SHALE AND SILTSTONE. THESE DARK CHLORITIC VEINS COMMONLY CONTAIN PYRITE IN QUARTZ VEINLETS WHICH ARE MORE OR LESS CENTRAL TO THE CHLORITE. THESE VEINS ARE OF VARYING ORIENTATION - IN THIS SLIDE SOME OF THEM ARE ALIGNED IN CLEAVAGE.

SLIDE 23 (PRINT

CHLORITE IS NOT COMMON IN THE SANDSTONE OF THE EASTERN SEDIMENTARY UNIT, ALTHOUGH CHLORITIC VEINS DO OCCUR SPORADICALLY. THIS SLIDE SHOWS A CHLORITIC VEIN WITH DISSEMINATED PYRITE TRAVERSING SANDSTONE AND IN TURN BEING CUT BY QUARTZ VEINS. THIS TYPE OF QUARTZ VEINING IS COMMON IN THE SANDSTONE.

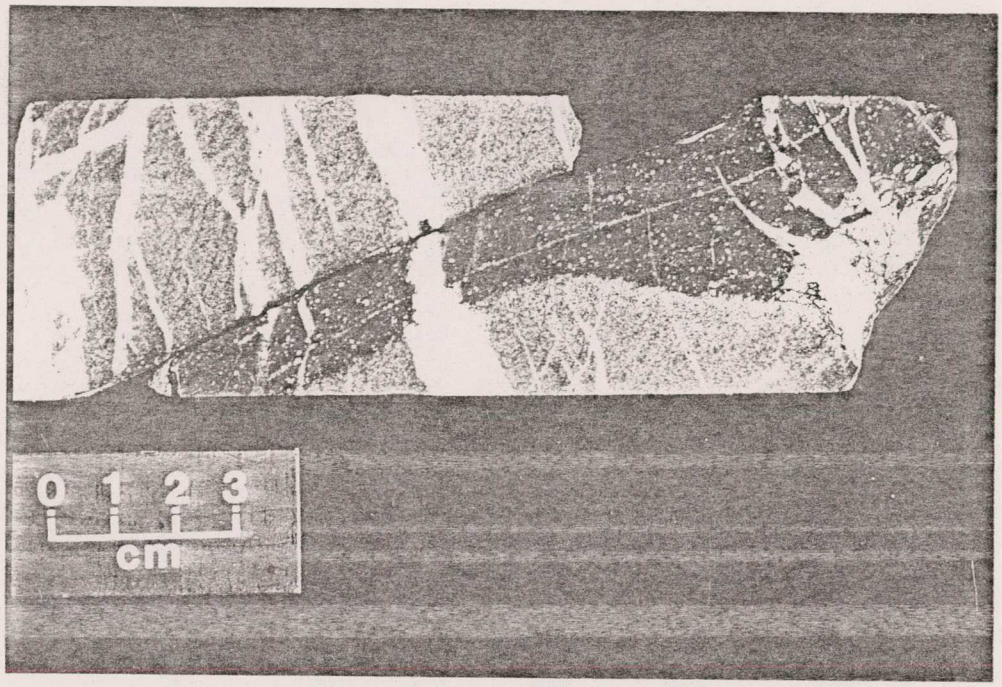
SLIDE 24 (PRINT

THIS SLIDE SHOWS AN IRREGULAR VEIN OF CHLORITE WITH SPHALERITE AND GALENA EXTENDING FROM THE BASE OF A CHLORITIC SHALE UNIT INTO UNDERLYING MASSIVE SANDSTONE.



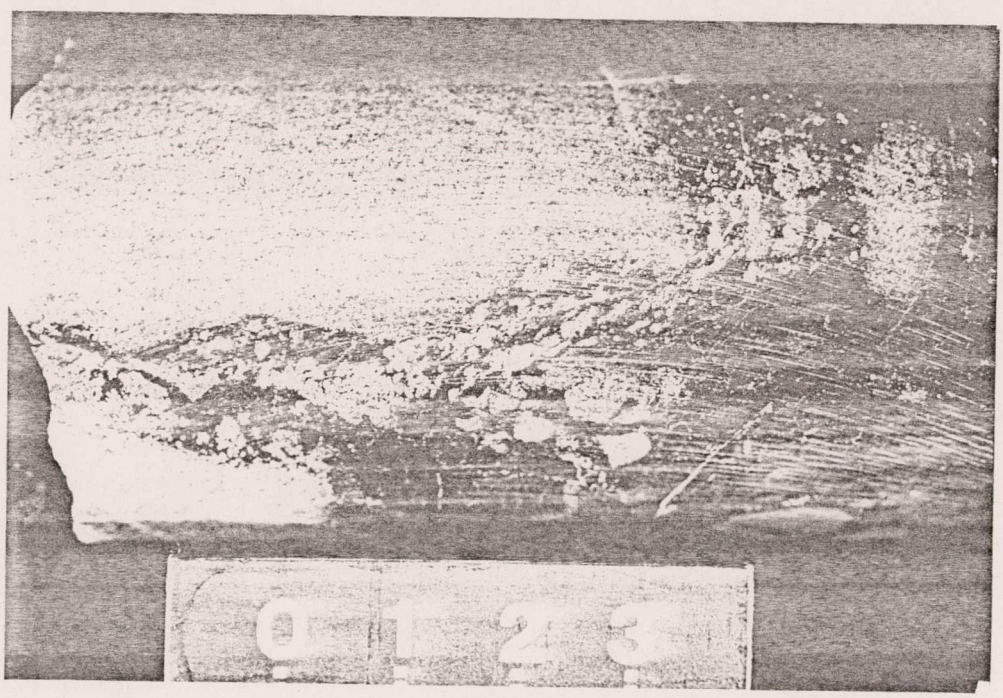
SLIDE 22 (PRINT)

Chloritic veins, partly aligned in cleavage, with pyrite, traversing lighter coloured sericitic shale and siltstone. Drill core DDH 6 (SHD-6) 144.0-144.15 m.



SLIDE 23 (PRINT)

Chloritic vein (very dark grey), with disseminated pyrite, traversing sandstone. Quartz veins cut sandstone and chloritic vein. Drill core DDH 2 (37S-2D) 228.6-228.75 m.



SLIDE 24 (PRINT)

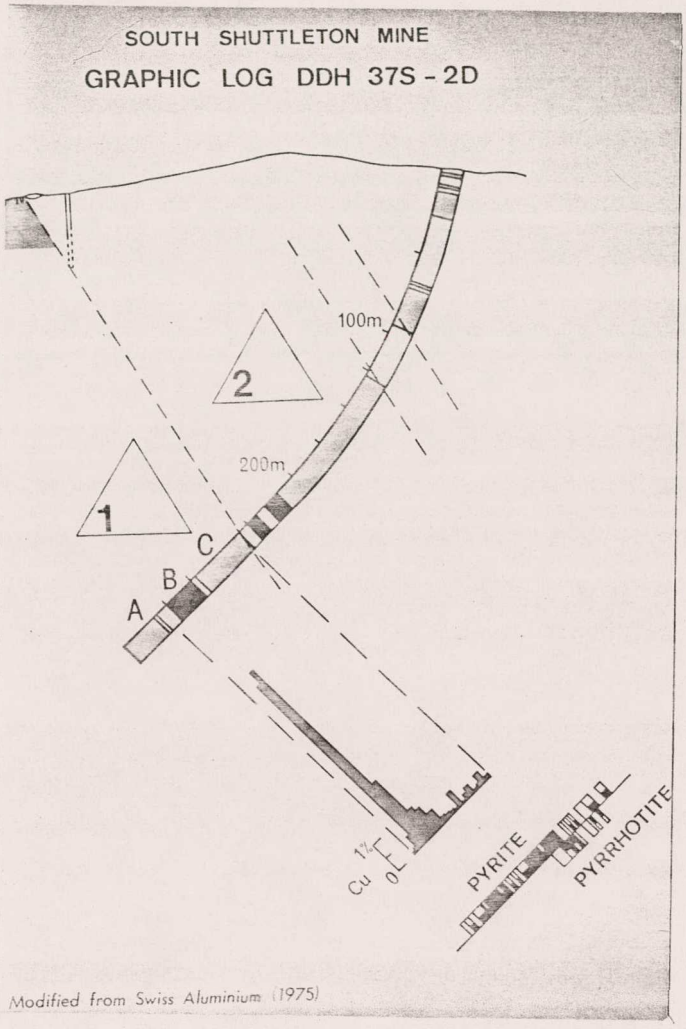
Irregular vein of chlorite (black), with sphalerite (brown) and galena (grey), in sandstone. Drill core DDH 7 (SHD-7) 215.0 m.

BECAUSE OF THE STRONG ASSOCIATION OF CHLORITE WITH MINERALIZATION IT WAS DECIDED TO STUDY THE COMPOSITION OF CHLORITE. WE ARE INDEBTED TO DR ERWIN SLANSKY OF THE NSW GEOLOGICAL SURVEY WHO UNDERTOOK ANALYSES OF CHLORITE USING A RAPID X-RAY DIFFRACTION TECHNIQUE DEVELOPED BY OINUMA ET AL. THIS METHOD MEASURES THE INTENSITIES OF THE THREE MAIN CHLORITE PEAKS. THESE ARE PLOTTED ON TRIANGULAR DIAGRAMS. CHARACTERISING THE CHLORITE IN THIS WAY SHOWS THAT THERE IS VARIATION IN CHLORITE COMPOSITION AT SHUTTLETON.

SLIDE 25 (PRINT)
SLIDE 25 (PLAN)
SLIDE 26 (PRINT)
SLIDE 26 (PLAN)

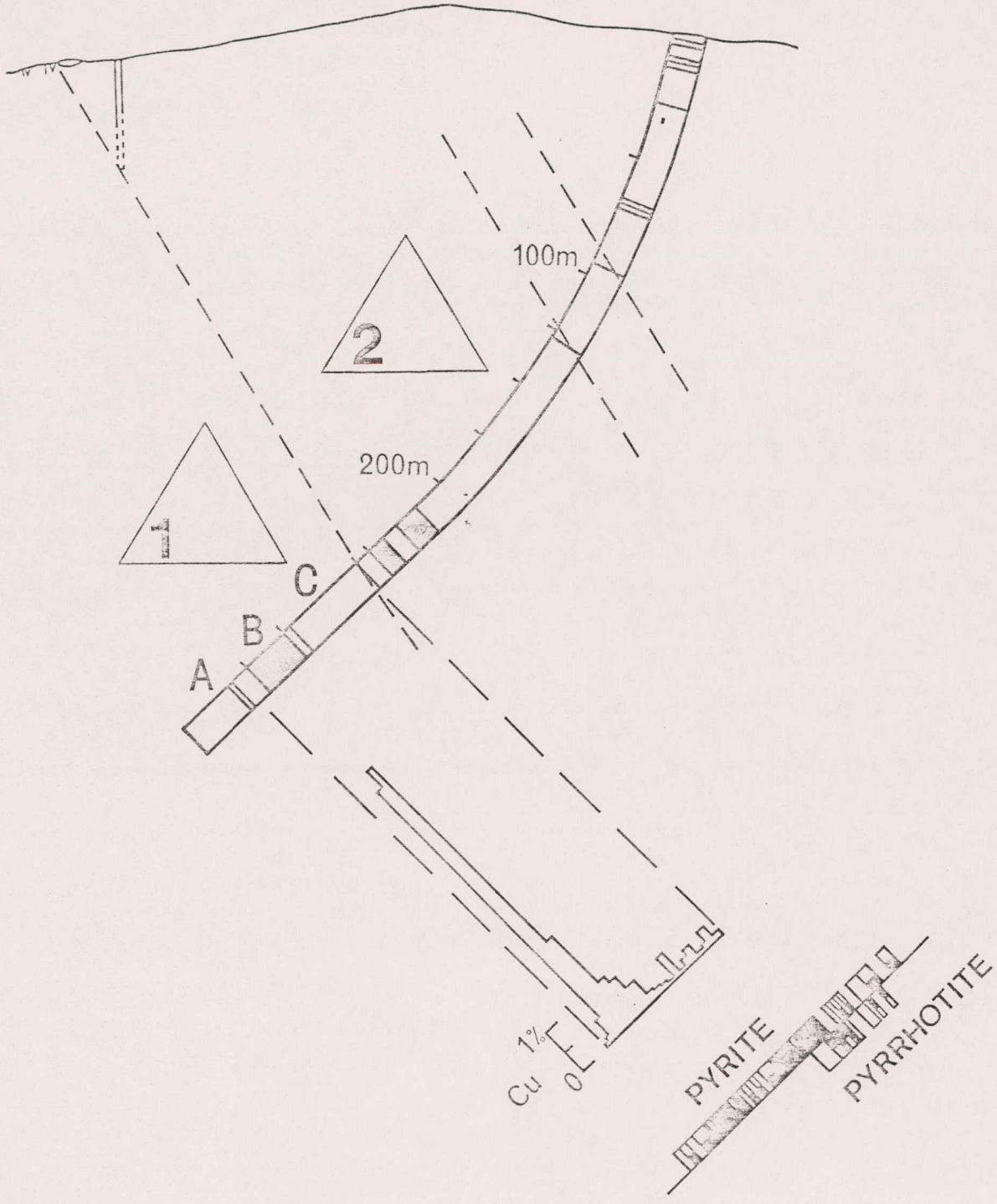
THIS IS BEST ILLUSTRATED IN DRILL HOLE 2D WHICH INTERSECTED THE STRONGEST MINERALIZATION AT SOUTH SHUTTLETON. WE HAVE SHOWN THE RESULTS FROM THE VOLCANIC UNIT IN THREE FIELDS, A, B, AND C. A IS THE FIELD FOR CHLORITE ANALYSES FROM BELOW THE MAIN MASSIVE SULPHIDE ZONE; B FROM THE MAIN MASSIVE SULPHIDE ZONE AND C FROM ABOVE THE MAIN MASSIVE SULPHIDE ZONE, ALTHOUGH SIGNIFICANT SULPHIDES ALSO OCCUR IN THIS INTERVAL. THE SECOND TRIANGLE SHOWS CHLORITE COMPOSITIONS FROM THE EASTERN SEDIMENTARY UNIT. THERE IS A MARKED INCREASE IN 7Å PEAK INTENSITY FOR CHLORITE SAMPLES HIGHER IN THE STRATIGRAPHY.

THERE ARE NO DATA ON THE CHEMICAL COMPOSITION OF CHLORITE AT SHUTTLETON AT THIS STAGE, BUT STUDIES USING THIS TECHNIQUE ELSEWHERE SUGGEST THAT THIS TREND REFLECTS AN INCREASE IN THE AMOUNT OF IRON IN THE CHLORITE AND PERHAPS AN INCREASE IN THE IRON TO IRON PLUS MAGNESIUM RATIO.



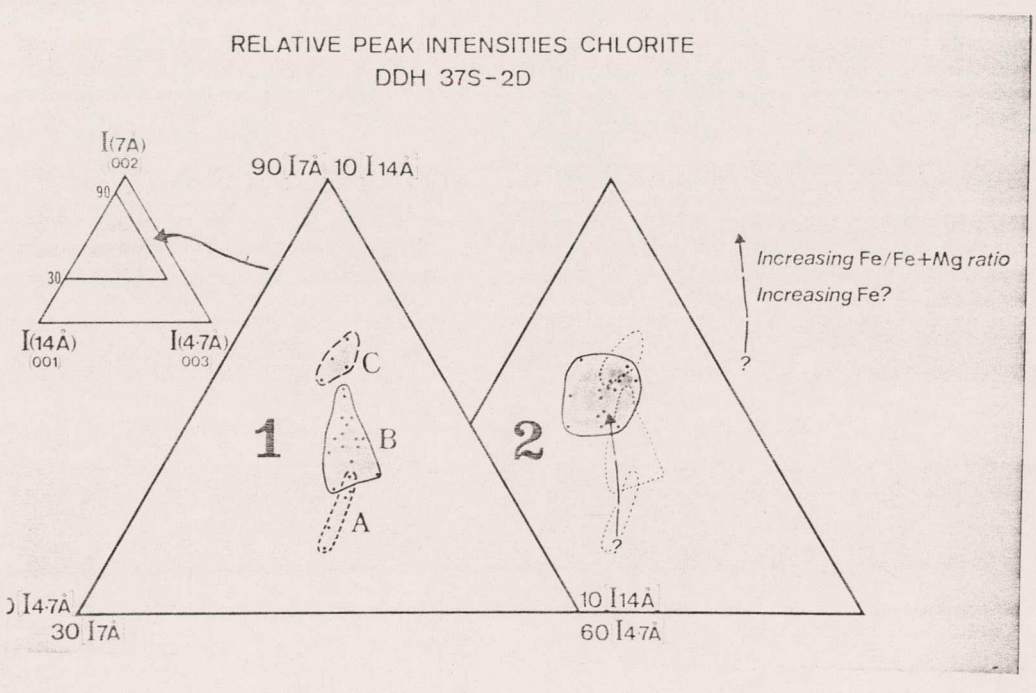
SLIDE 25 (PRINT)

SOUTH SHUTTLETON MINE
GRAPHIC LOG DDH 37S - 2D



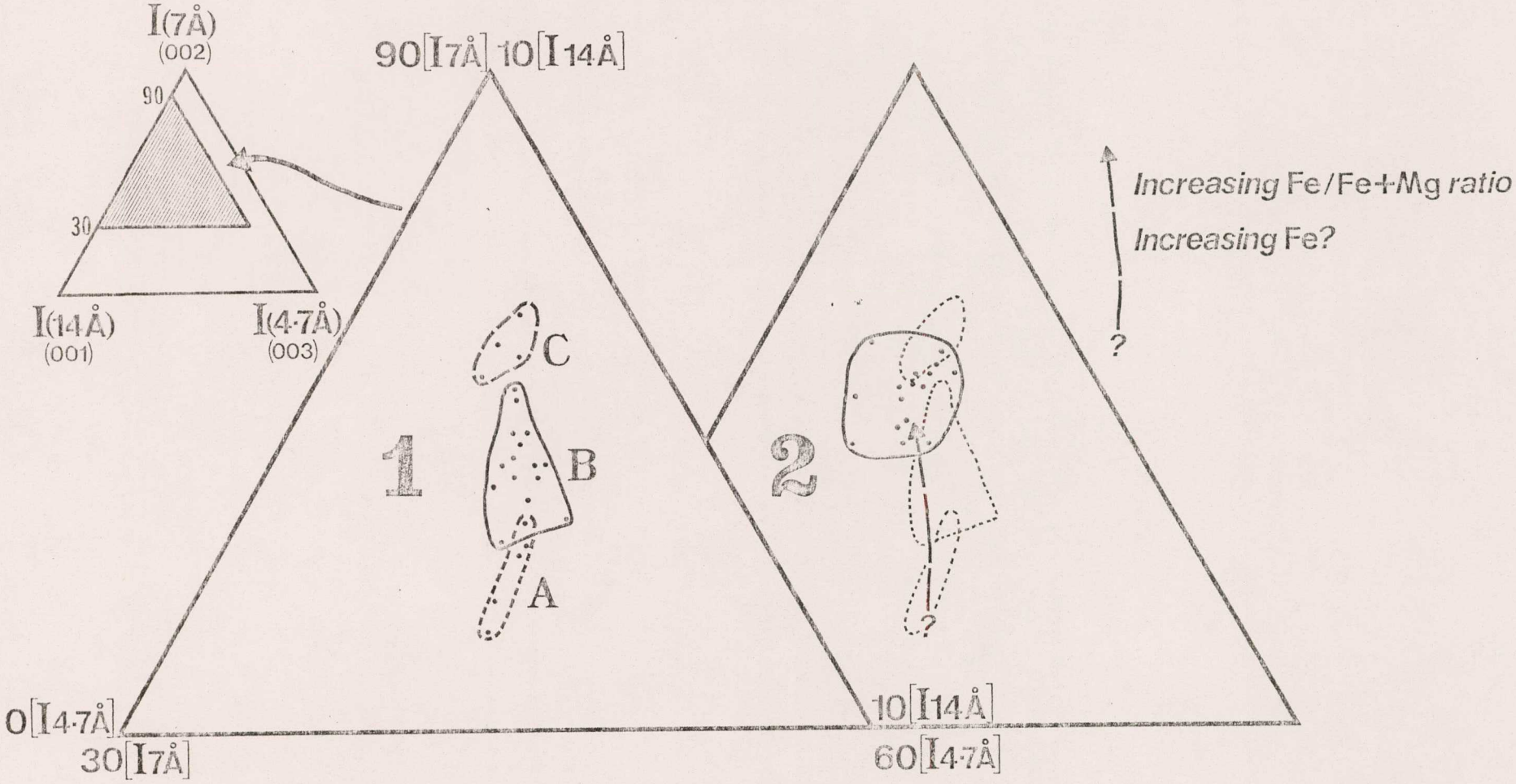
Modified from Swiss Aluminium (1975)

SLIDE 25 (PLAN)



SLIDE 26 (PRINT)

RELATIVE PEAK INTENSITIES CHLORITE
DDH 37S-2D



SLIDE 26 (PLAN)

GS1983/128

CHLORITE IN THE SHALES OVERLYING THE VOLCANIC UNIT PLOT CONSISTENTLY IN A FIELD OVERLAPPING CHLORITE COMPOSITION FROM THE UPPER PART OF THE VOLCANIC UNIT.

S L I D E 27 (PRINT
S L I D E 27 (PLAN)
S L I D E 28 (PRINT
S L I D E 28 (PLAN)

DRILL HOLE NUMBER 6 WAS DRILLED CLOSE TO HOLE 2D, BUT DID NOT INTERSECT STRONG MINERALIZATION. THE PLOTS OF CHLORITE PEAK INTENSITIES FROM BOTH VOLCANIC AND OVERLYING SHALE UNITS FALL APPROXIMATELY IN THE SAME FIELD, APART FROM A FEW MINERALIZED SAMPLES IN THE VOLCANIC UNIT.

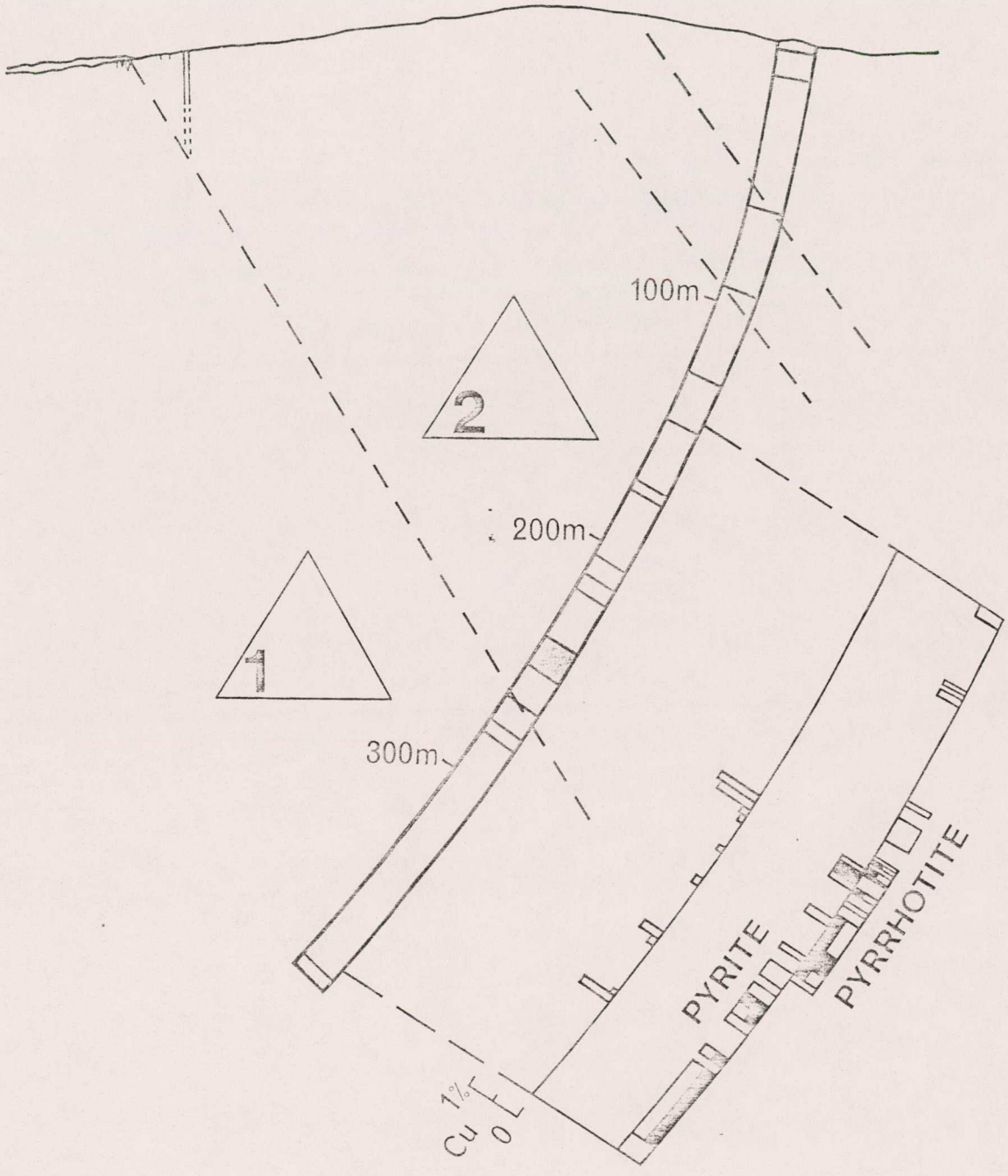
A FEW ANALYSES OF CHLORITE FROM DARK CHLORITIC VEINS AND NEARBY LIGHTER COLOURED SHALE IN AN UPPER SHALE UNIT INDICATE LITTLE DIFFERENCE IN CHLORITE COMPOSITION. THE VEINS DIFFER ESSENTIALLY IN CONTAINING MORE CHLORITE AND LESS WHITE MICA AND QUARTZ THAN THE SHALE.

(S L I D E 26)

THE VARIATION IN CHLORITE COMPOSITION MAY MEAN:

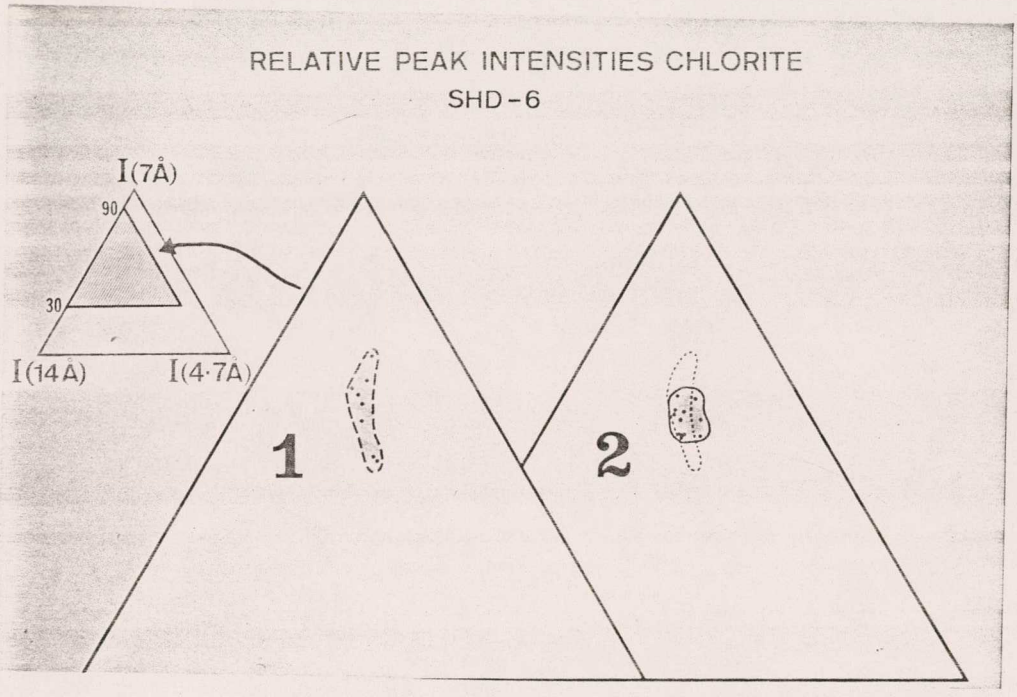
- FIRSTLY THERE HAS BEEN ENRICHMENT IN MAGNESIUM IN CHLORITE IN THE VOLCANIC UNIT IN BOTH FELSIC VOLCANIC OR VOLCANICLASTIC ROCKS AND IN THE SHALES WHICH CONTAIN THE STRONGEST MINERALIZATION. MINOR TALC ALSO OCCURS. THIS IS SPECULATIVE AT THIS STAGE, UNTIL SOME CHEMICAL

SOUTH SHUTTLETON MINE
GRAPHIC LOG DDH SHD-6

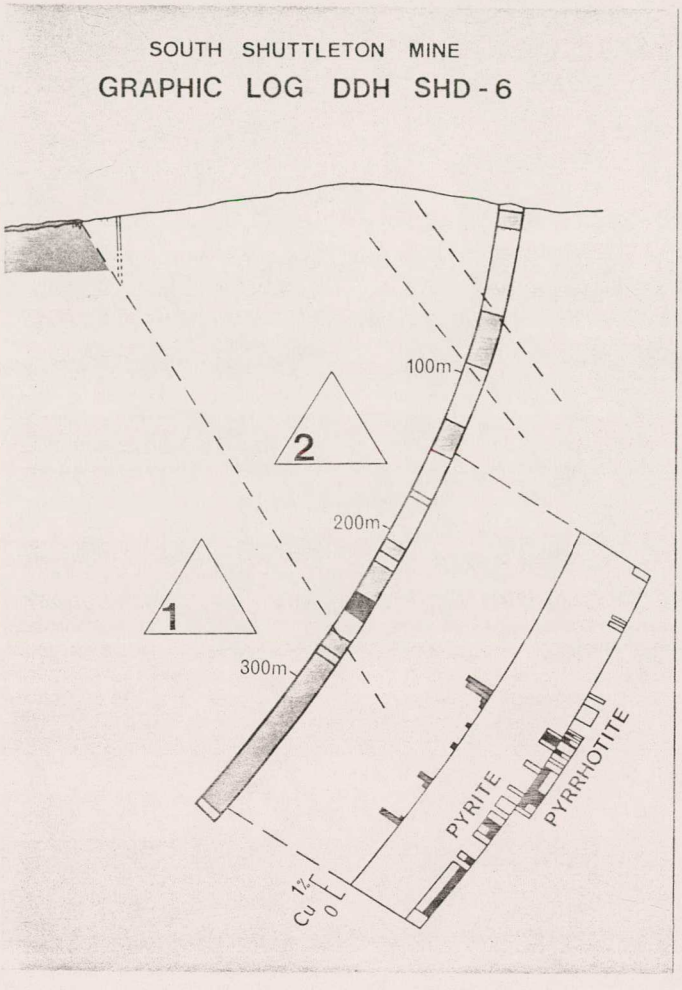


Modified from Swiss Aluminium (1975)

SLIDE 27 (PLAN)

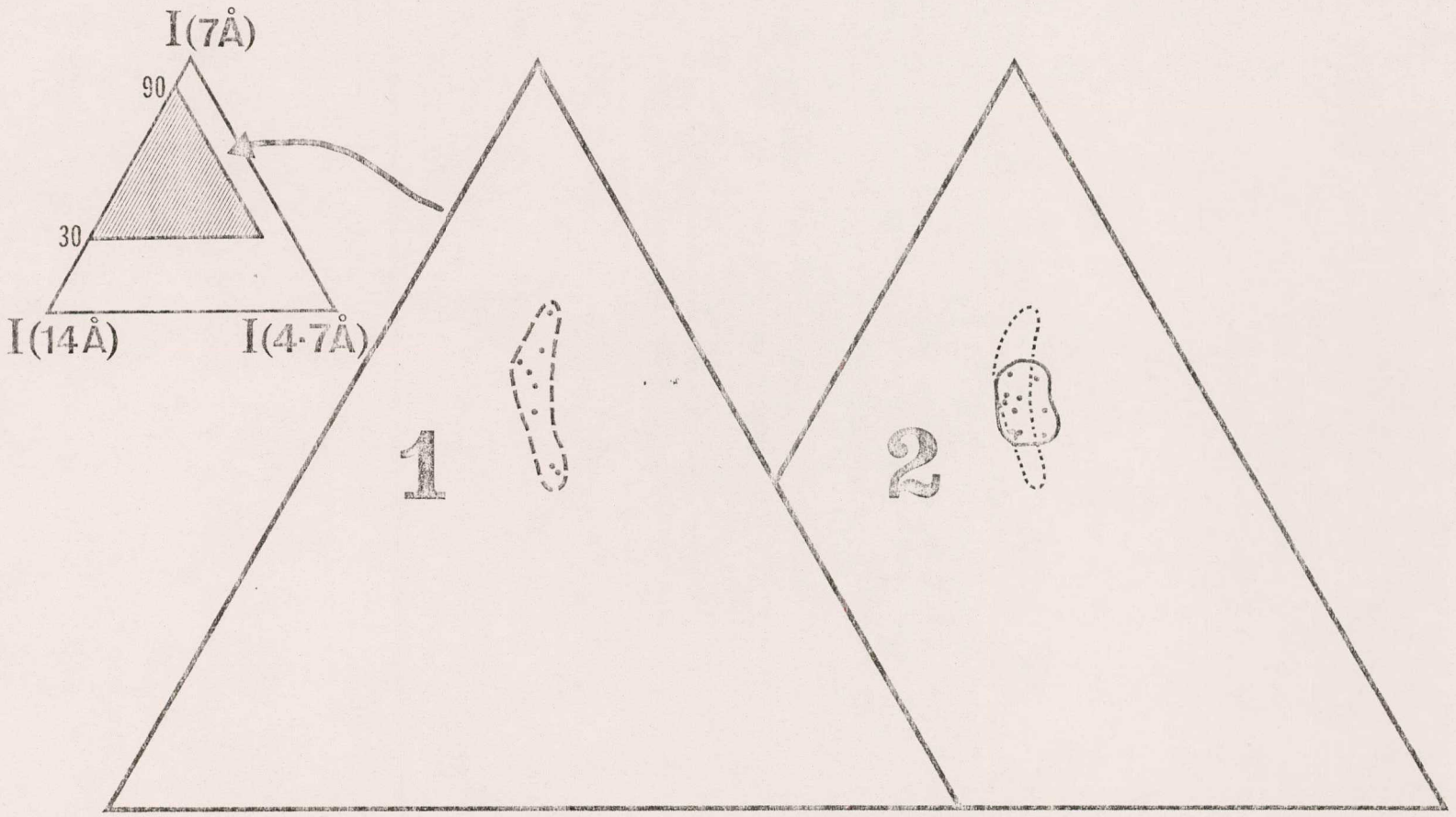


SLIDE 28 (PRINT)



SLIDE 27 (PRINT)

RELATIVE PEAK INTENSITIES CHLORITE
SHD-6



SLIDE 28 (PLAN)

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- SECONDLY PERHAPS THERE WAS NO ALTERATION IN CHEMICAL COMPOSITION IN IRON RICH CHLORITE CHARACTERISTIC OF THE SHALES OVERLYING THE VOLCANIC UNIT.

  NEVERTHELESS, THE OCCURRENCE OF CHLORITE-RICH VEINS IN THE SHALES INDICATES THERE HAS BEEN SOME FORM OF ALTERATION.

THE CHLORITE RICH SULPHIDE-BEARING VEINS TRAVERSING THE LIGHTER COLOURED SHALE WHICH CONTAINS CHLORITE OF SIMILAR COMPOSITION MAY HAVE FORMED BY LOCAL METAHYDROTHERMAL REMOBILIZATION, RATHER THAN BY INVASION OF ORE FORMING SOLUTIONS.

IF THE VEIN-LIKE CHLORITE WAS FORMED BY PERVASIVE ALTERATION WHICH ACCOMPANIED DEPOSITION OF SULPHIDES IN THE STRONGLY MINERALIZED SECTIONS OF THE VOLCANIC UNIT, WE WOULD EXPECT AT LEAST SOME CHLORITE FROM HIGHER IN THE STRATIGRAPHY TO PLOT IN THE LOWER IRON FIELD OF CHLORITE FROM THE MINERALIZED PORTION OF THE VOLCANIC UNIT.

SUMMARY

SLIDE 29(PLAN)

TO SUMMARIZE, WE COULD MAKE THE FOLLOWING POINTS:

(SLIDE 2)

1 THE DEPOSITS IN THE SHUTTLETON AREA OCCUR WITHIN FELSIC VOLCANIC ROCKS AND PROBABLY RESULT FROM VOLCANIC PROCESSES.

THE TECTONIC AND REGIONAL STRUCTURAL SETTING OF THE SHUTTLETON-WIRLONG AREA IS NOT CLEAR, BUT VOLCANISM MAY HAVE BEEN CONTROLLED BY MERIDIONAL RIFT-TYPE FAULTING.

(SLIDE 8)

2 AT SHUTTLETON MINERALIZATION IS CONFINED TO A HETEROGENEOUS SEQUENCE OF FELSIC PYROCLASTIC ROCKS, VOLCANICLASTIC SEDIMENTS, SHALE, SILTSTONE AND SANDSTONE. THE DEPOSIT AT SOUTH SHUTTLETON CONSISTS OF BOTH MASSIVE AND STOCKWORK VEIN-TYPE MINERALIZATION WHICH, BROADLY SPEAKING, IS STRATABOUND.

THERE IS A ZONING OF PYRITE AND PYRRHOTITE, WITH PYRITE TENDING TO BE THE DOMINANT IRON SULPHIDE IN STRATIGRAPHICALLY LOWER SECTIONS OF THE SEQUENCE.

STRONGEST MINERALIZATION OCCURS IN SHALE AND SILTSTONE WITHIN THE VOLCANIC UNIT.

SUMMARY

STRUCTURAL/TECTONIC SETTING

:Rift?

STRATIGRAPHIC SETTING

:Stratabound, felsic volcanic-sedimentary unit

DEFORMATION

:Brittle and ductile sulphide deformation, metahydrothermal remobilization in folded and cleaved host rocks

ALTERATION

:Variation in chlorite composition, ?Mg enrichment, minor talc

ORIGIN

:Volcanic exhalative

(S L I D E 16)

3 THERE IS STRONG EVIDENCE THAT MINERALIZATION HAS BEEN DEFORMED. PROBABLY THIS DEFORMATION OCCURRED DURING THE FORMATION OF FOLDS AND CLEAVAGE SEEN THROUGHOUT THE SHUTTLETON-WIRLONG AREA.

SULPHIDE MINERALS HAVE RESPONDED DIFFERENTLY DURING DEFORMATION. CHALCOPYRITE AND PYRRHOTITE UNDERWENT DUCTILE DEFORMATION AND PYRITE UNDERWENT BRITTLE DEFORMATION.

SANDSTONE, SILTSTONE AND SHALE WERE MUCH LESS DUCTILE THAN THE SULPHIDES.

(S L I D E 26)

4 X-RAY DIFFRACTION STUDIES INDICATE THAT CHLORITE COMPOSITION VARIES SYSTEMATICALLY. THERE IS A CONTRAST BETWEEN CHLORITE IN THE VOLCANIC UNIT, ESPECIALLY IN STRONGLY MINERALIZED SECTIONS, AND CHLORITE IN OVERLYING SHALE. WE ASSUME THAT THE CHLORITE IN THE VOLCANIC UNIT IS RELATIVELY RICH IN MAGNESIUM ALTHOUGH THIS HAS NOT BEEN CONFIRMED BY CHEMICAL ANALYSIS. THIS PATTERN WOULD BE CONSISTENT WITH ALTERATION DURING MINERALIZATION WHICH RESULTED IN MAGNESIUM ENRICHMENT. THIS TYPE OF ALTERATION HAS BEEN RECORDED IN MANY DEPOSITS IN FELSIC VOLCANIC ROCKS AND HAS BEEN OUTLINED IN GEOLOGICAL SURVEY STUDIES OF FELSIC VOLCANIC ROCKS AT MOUNT HOPE. THE MINOR TALC-CARBONATE OCCURRENCES IN THE VOLCANIC UNIT AT SHUTTLETON PROBABLY ALSO ARE A RESULT OF MAGNESIUM ENRICHMENT.