GEOCHEMICAL PATEREN OF ORE SISTEMS FROM REGIONAL TO LOCAL-BASED ON IONEX TECHNOLOGY

Issai Goldberg and Grigory Abramson

Introduction

- In current practice, geochemical exploration of mineral deposits is directed at verifying the presence of anomalous (above background) concentrations of ore elements. These concentrations are a result of the primary process of ore formation and/or the disintegration of deposits in the form of haloes of secondary dispersion.

Introduction

- In “Geochemistry in Mineral Exploration” by Rose et al., (1979) these are presented as four general criteria for appraising favorable areas: “(i) the magnitude of the values metal above background; (ii) the size and shape anomalies areas; (iii) geological setting and; (iv) the extend to which the local environment may have influenced the metal content and the pattern of the anomaly”.

Introduction

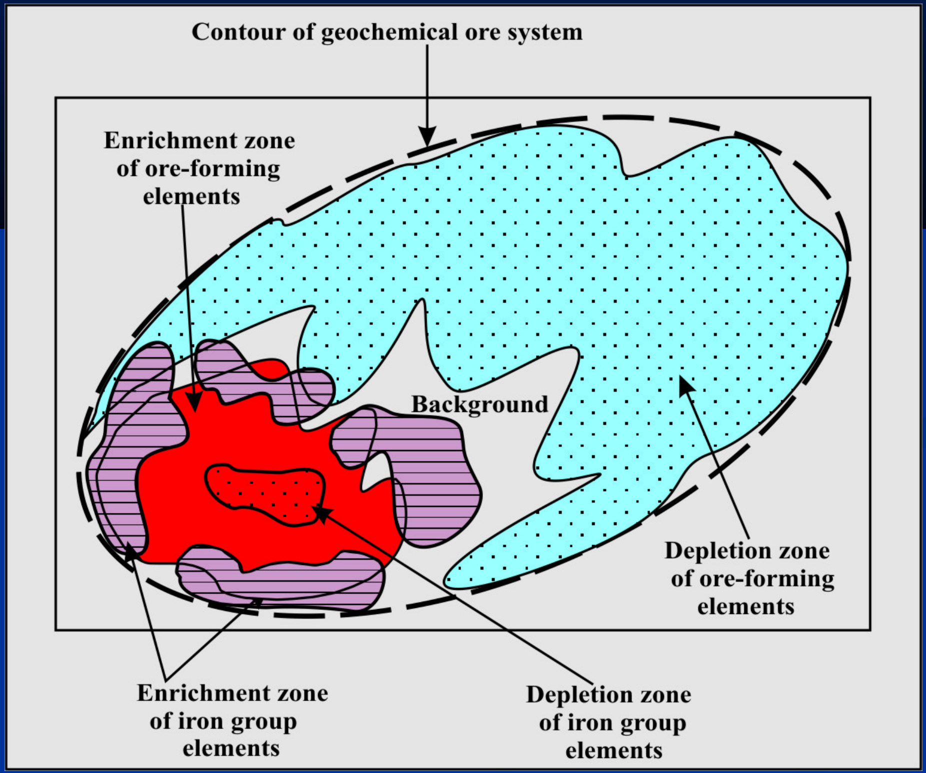
- Problems of appraising a favourable anomaly could be largely overcome by considering another criterion which is currently almost ignored: the presence of depletion zones in ore regions, which are manifest in pairs with enrichment zones. Such pair patterns can be outlined as unified polar geochemical systems

MODEL OF POLAR GEOCHEMICAL ORE SYSTEM

The fundamental features of a polar geochemical ore system include:

- **polar zoning of distribution of ore-forming elements,**
- **polar zoning of distribution of iron group elements**

Geochemical systems are fractal (self-similarity) and occur at all scales.



Areas of investigation

Australia

Canada

China

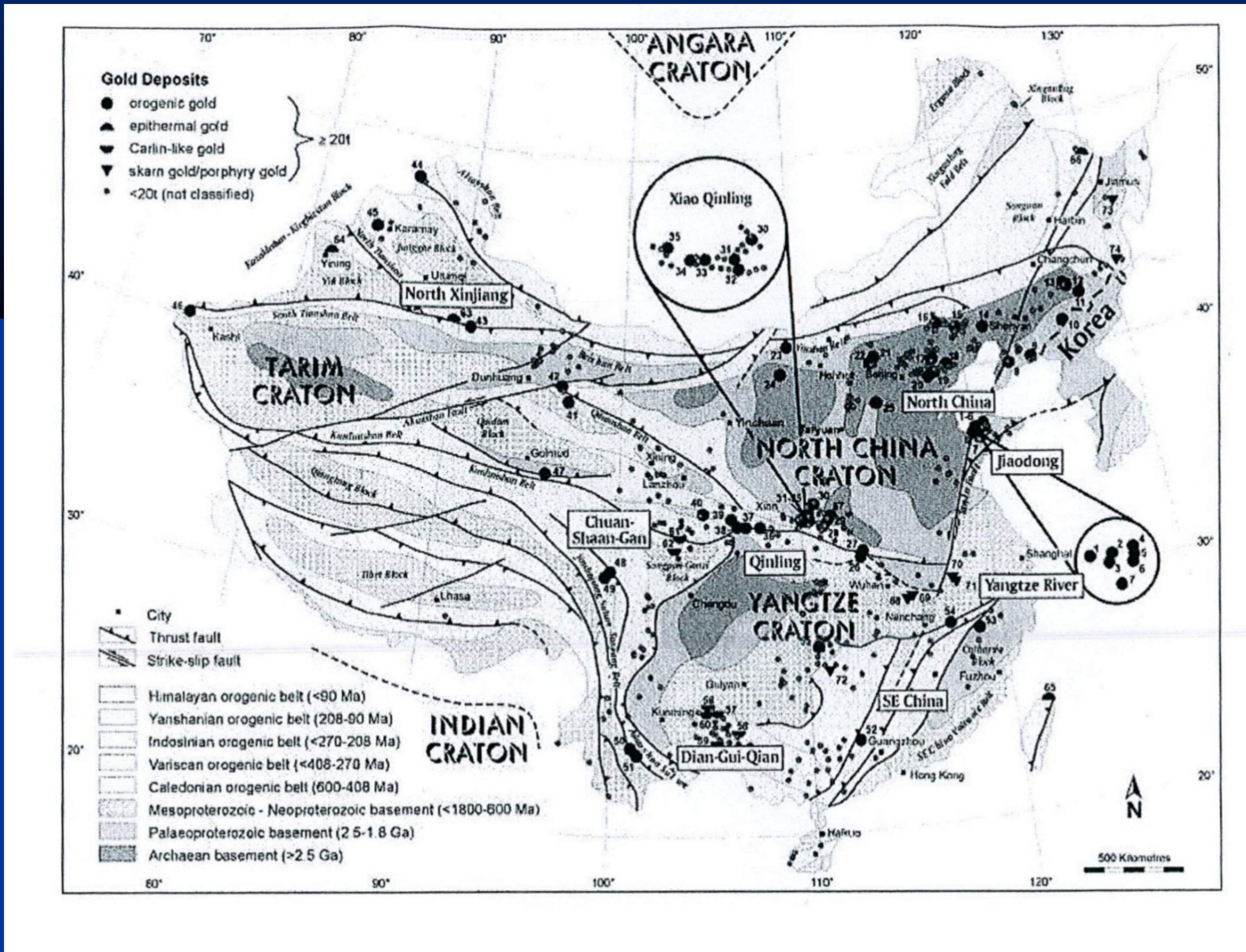
Kazakhstan

North America

Russia

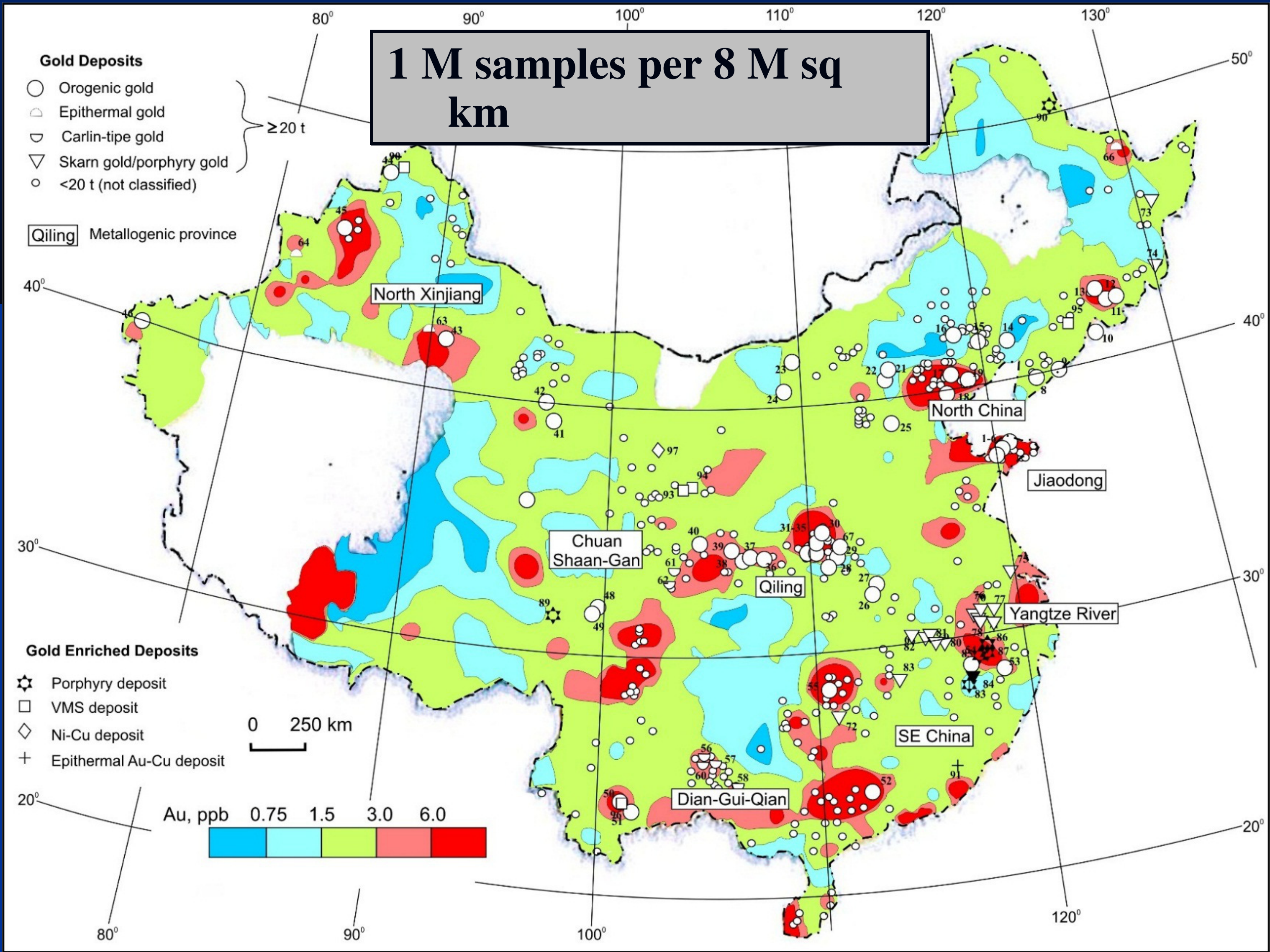
Spain

GOLD DEPOSITS AND TECTONICS OF CHINA
After Zhou et al 2002



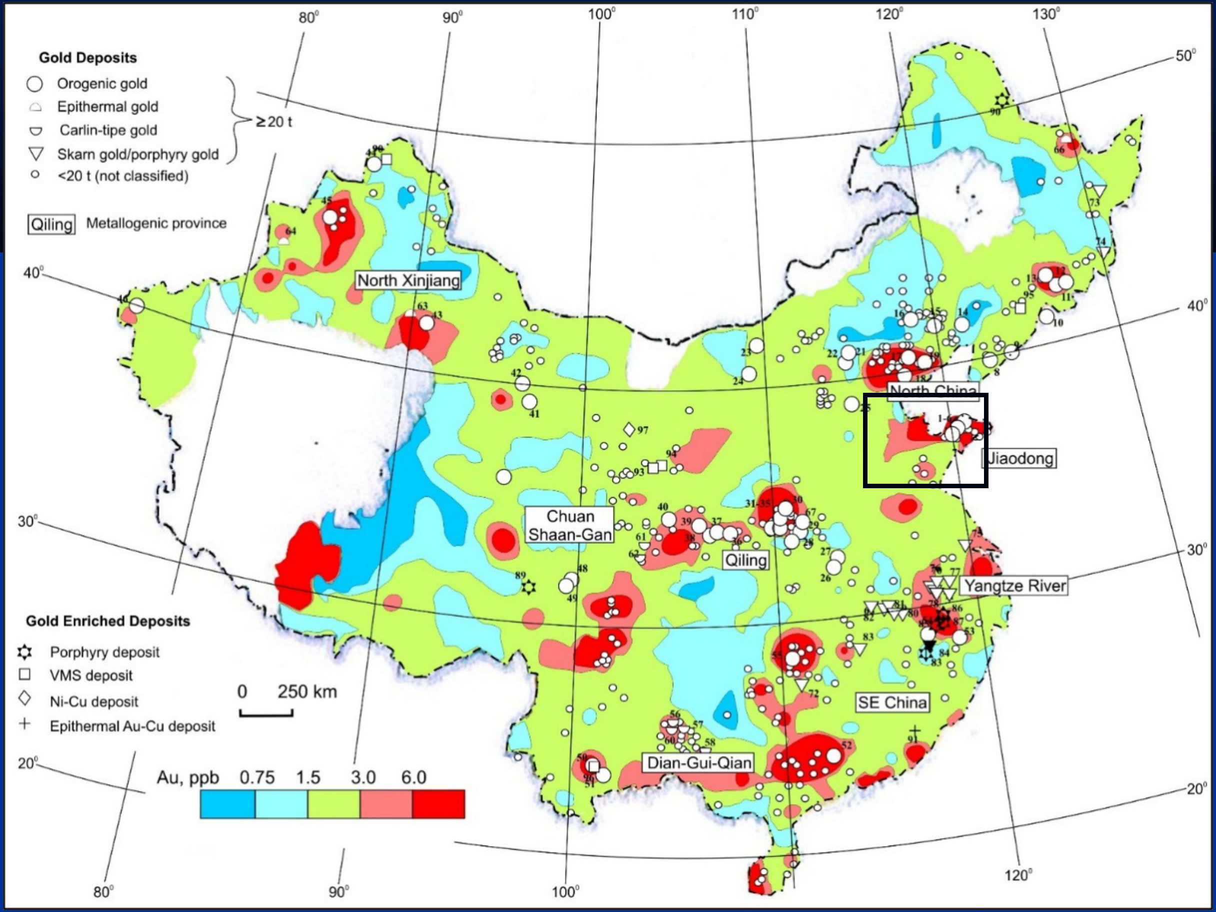
There are 97 different types of gold deposits with resources of more then Au 20 т (4500 t in total)

LOCATION OF GOLD REPOSIT AND DISTRIBUTION OF GOLD IN STREAM SEDIMENTS



after Xie, 2008

LOCATION OF GOLD REPOSIT AND DISTRIBUTION OF GOLD IN STREAM SEDIMENTS



Enriched zones > 3 ppb

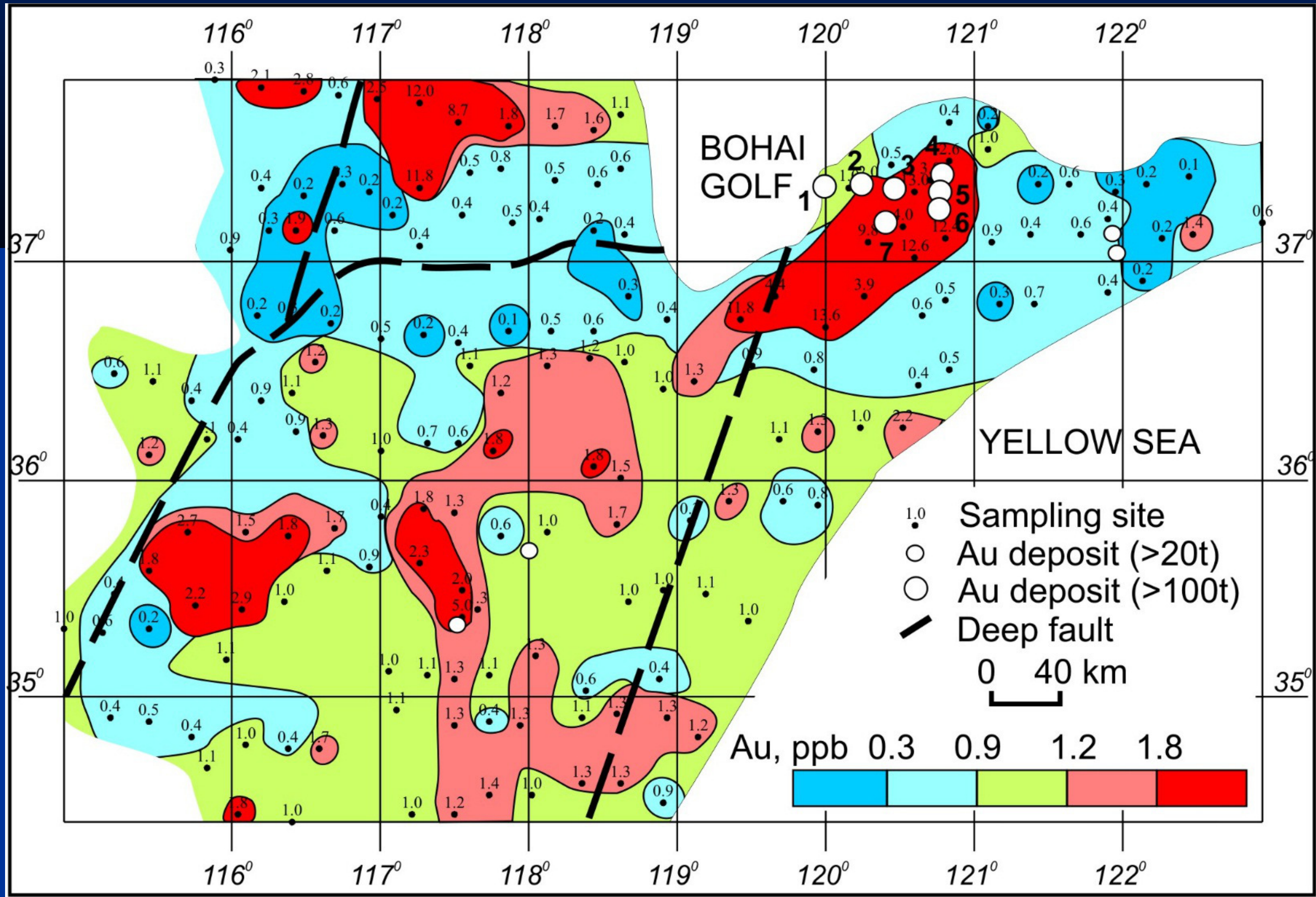
Area – 1.7 M sq km.

Depleition zones < 1.5 -0.75 ppb

Area – 2.7 M sq km.

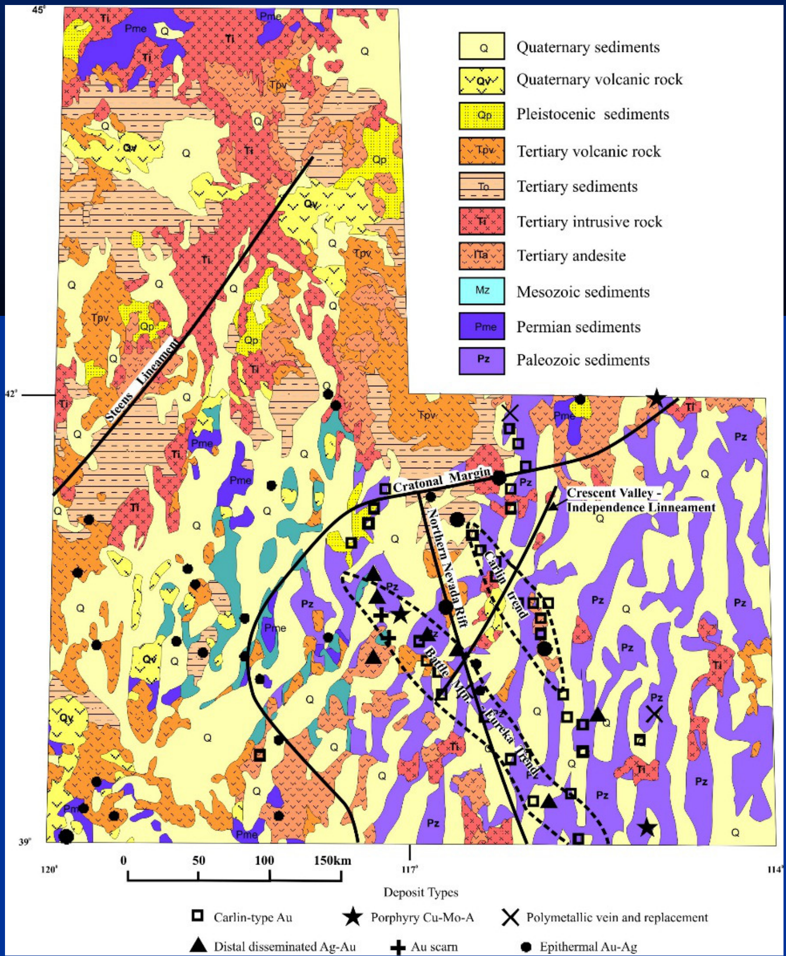
The geochemical system areas – n*100,000 sq km

DISTRIBUTION OF GOLD IN SOIL
NORTH PROVINCE
150,000 sq km

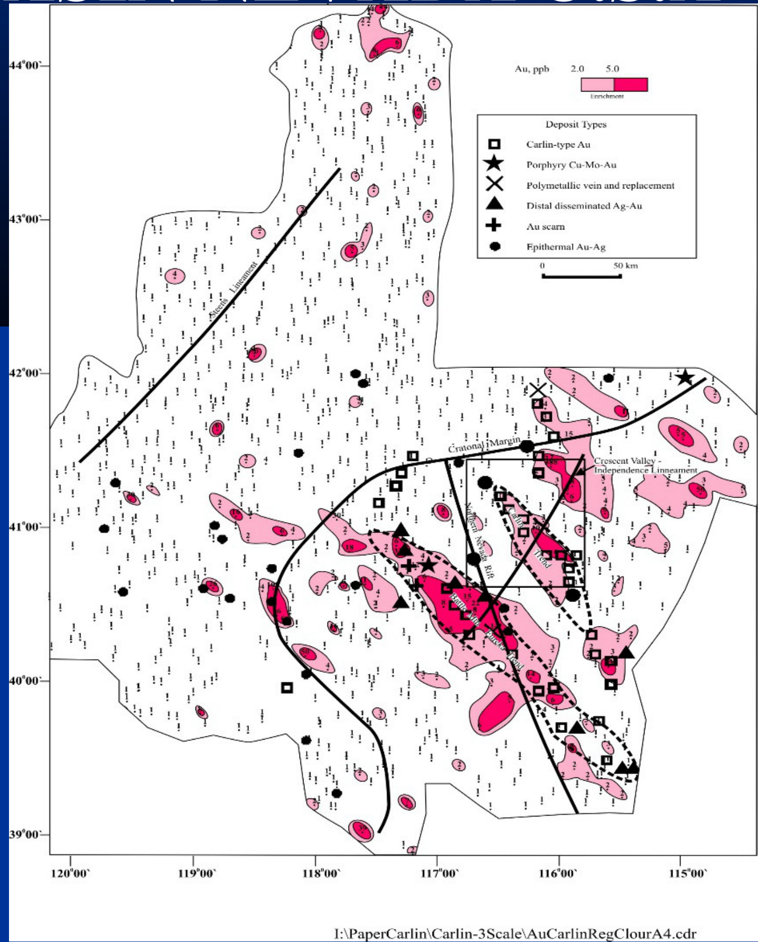


After Wang et al. 1997

GOLD PROVINCE
NORTHERN GREAT BASIN NEVADA U.S.A



Geological map 1 : 1.500 000
S - 165, 000 sq.km



Distribution of Gold 1 : 1.500 00
Enrichment zones of Au – 20 000 sq.km
Open-File 02-0227, USGS, Coombs et al 2002

GOLD PROVINCE
NORTHERN GREAT BASIN NEVADA U.S.A

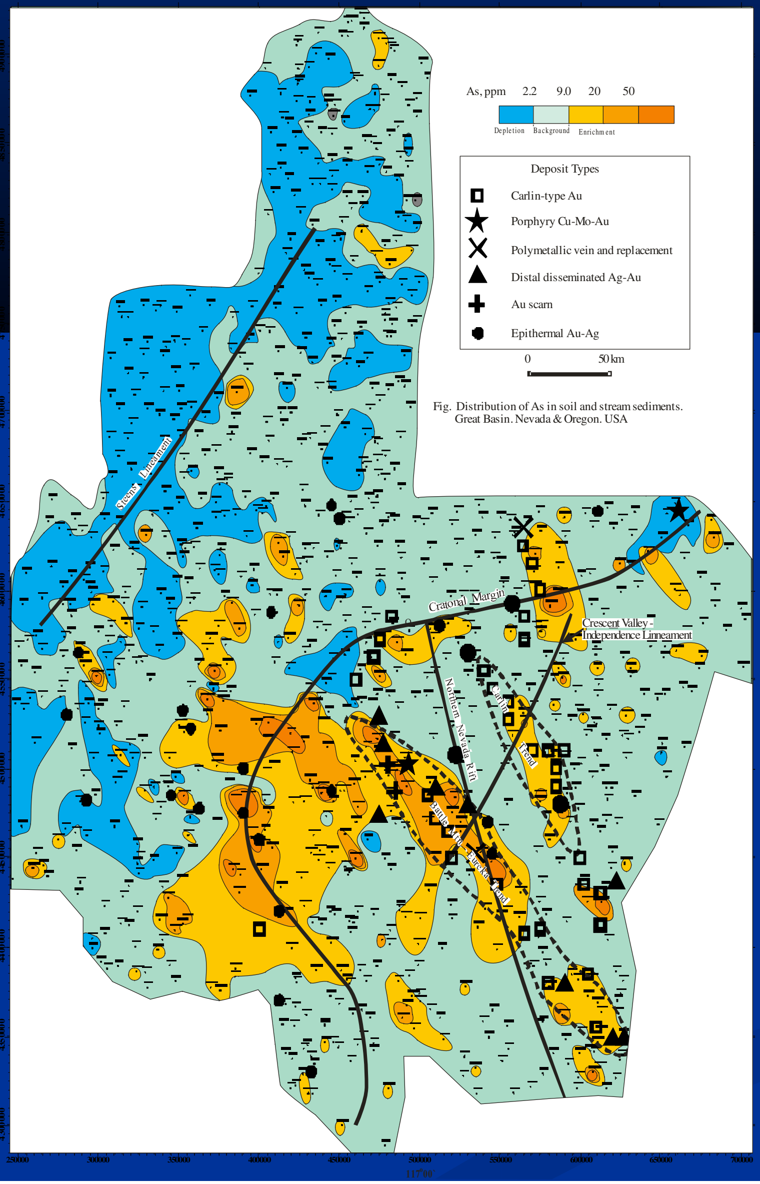
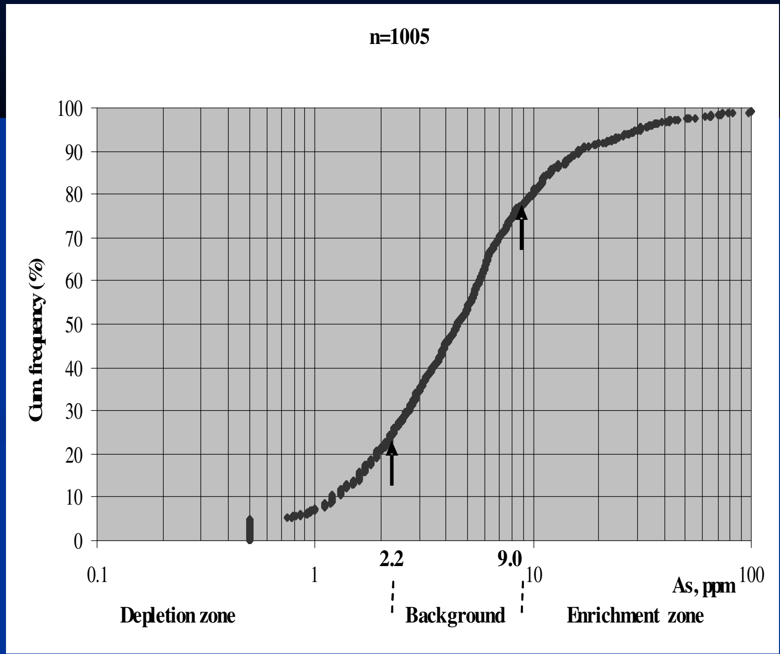
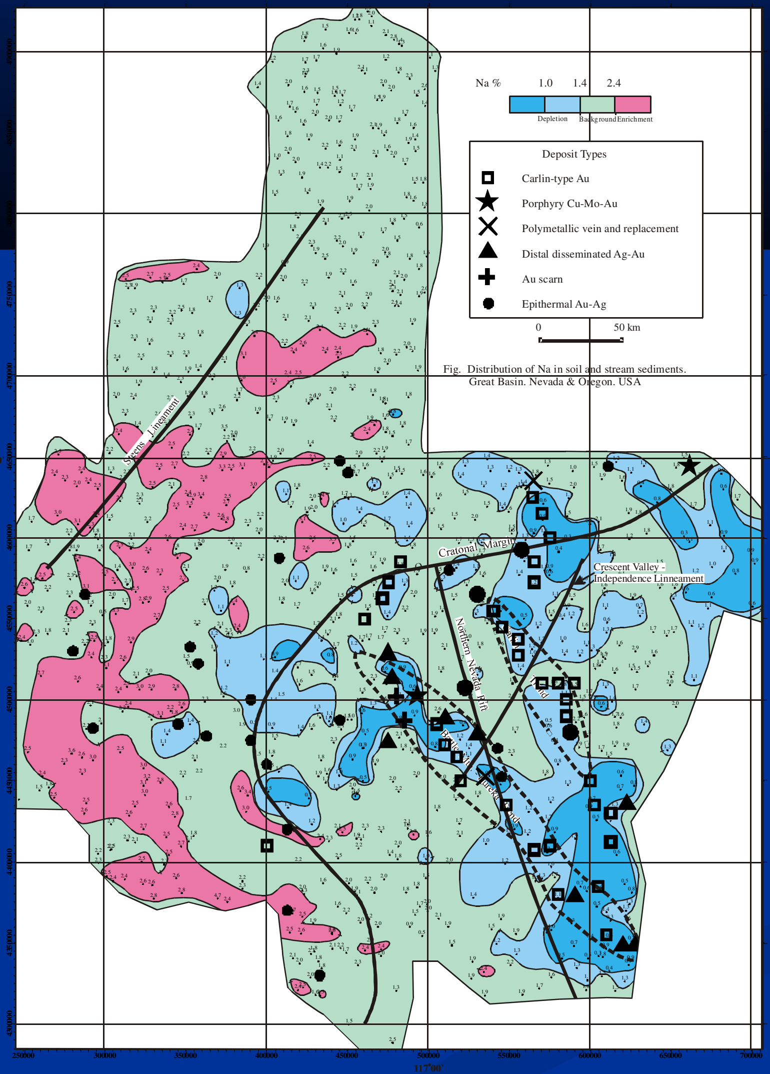


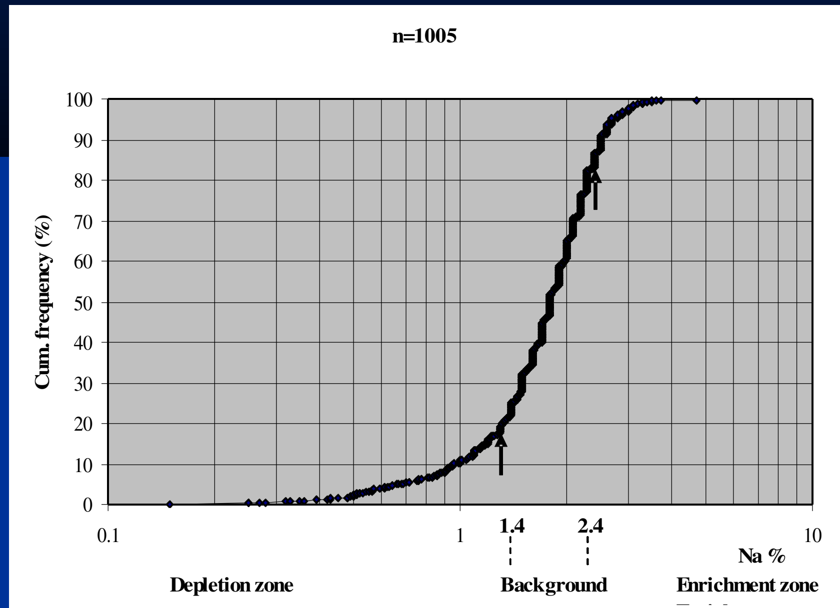
Fig. Distribution of As in soil and stream sediments. Great Basin. Nevada & Oregon. USA



Cumulative distribution plot of As

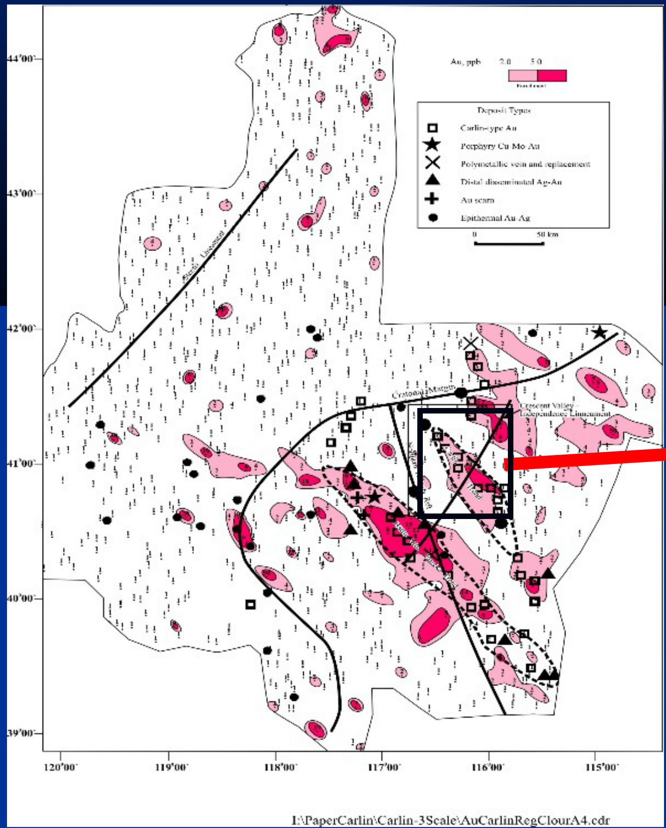
GOLD PROVINCE
NORTHERN GREAT BASIN NEVADA U.S.A

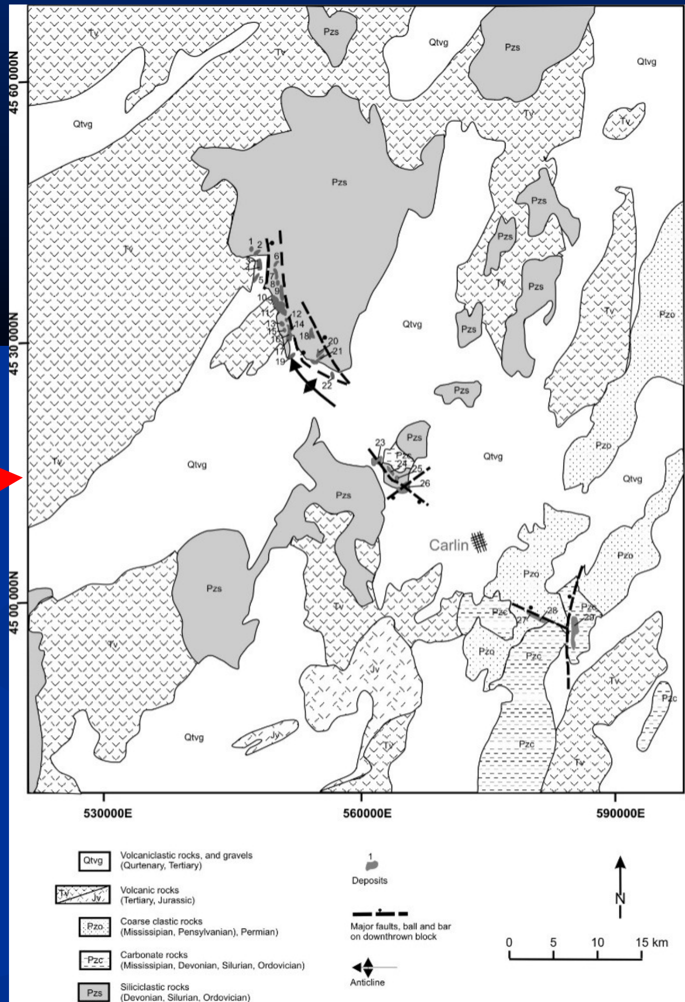




Cumulative distribution plot of Na

CARLIN-TREND GOLD DEPOSITS
USA





Carlin –Trend Ore –Region scale

Area – 7 000 sq. km

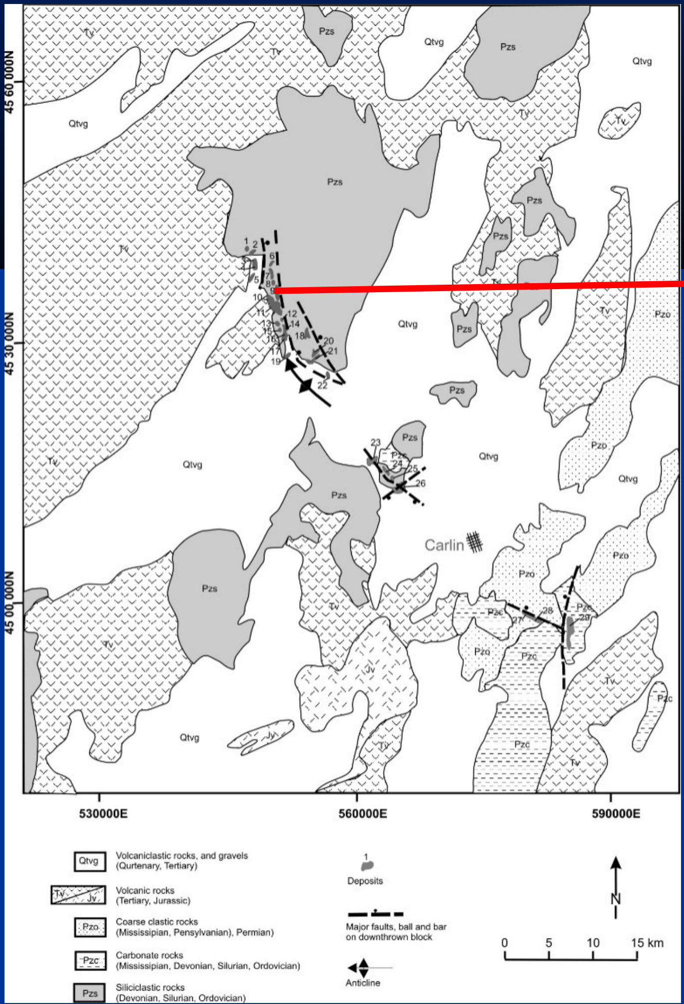
After Teal и Jackson, 1997; Ressel

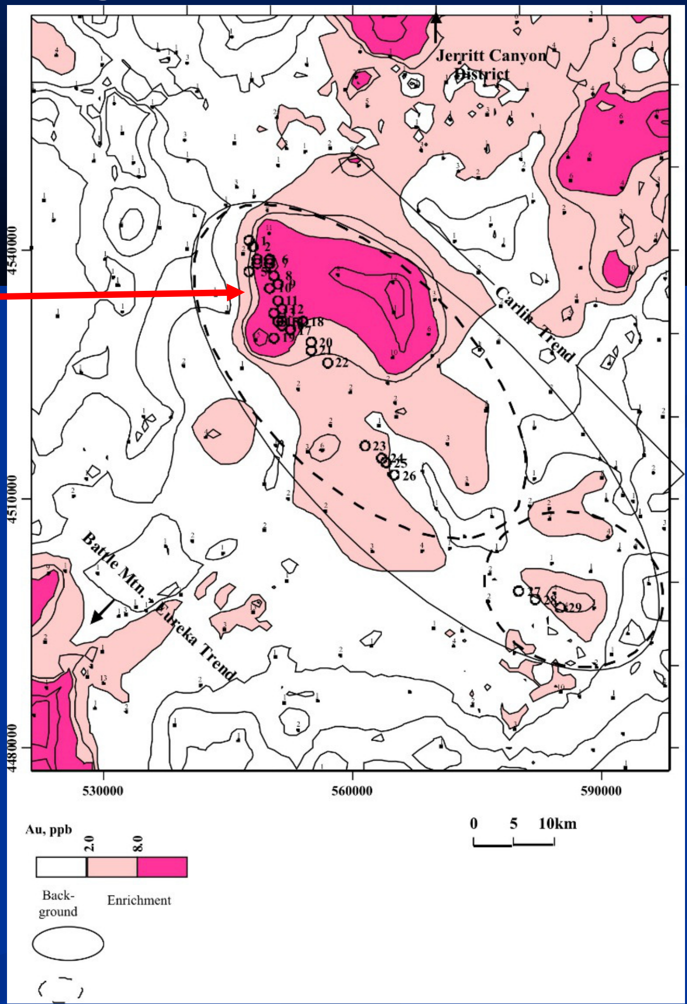
и

Scale **1 : 500 000**

Henry , 2006)

CARLIN-TREND GOLD DEPOSITS
USA
Distribution of gold

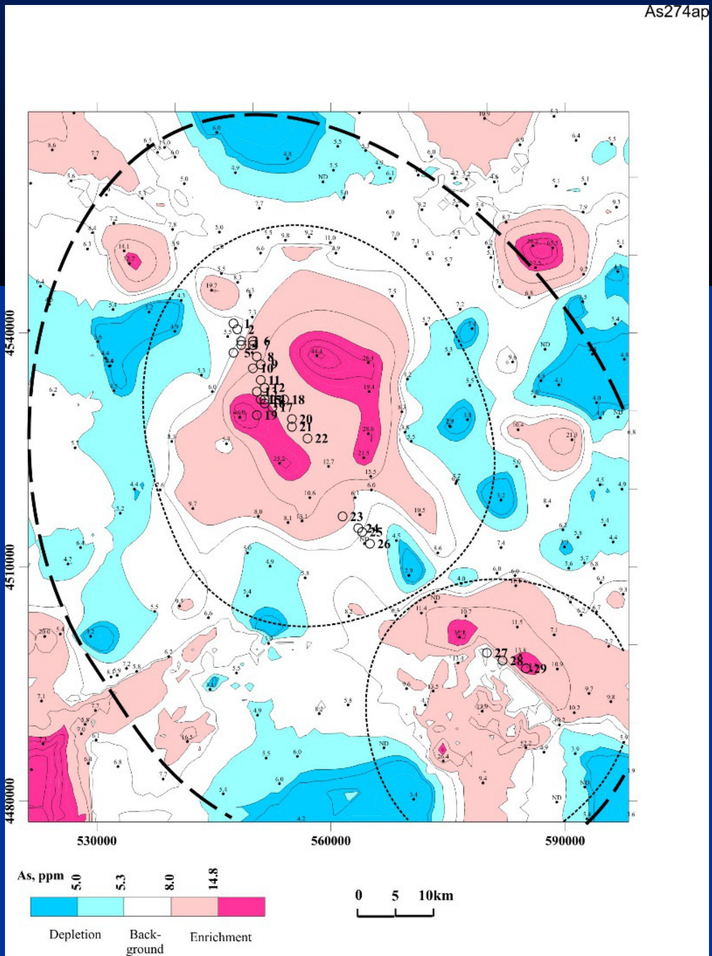




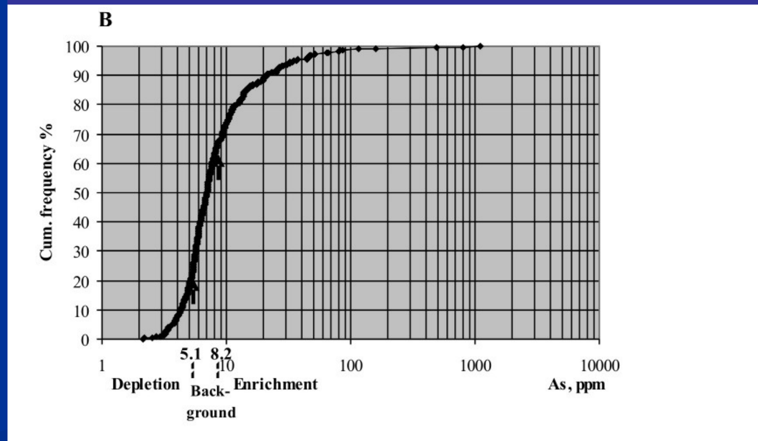
Enrichment zones of Au -2320 sq km

CARLIN-TREND GOLD DEPOSITS
USA

Distribution of As



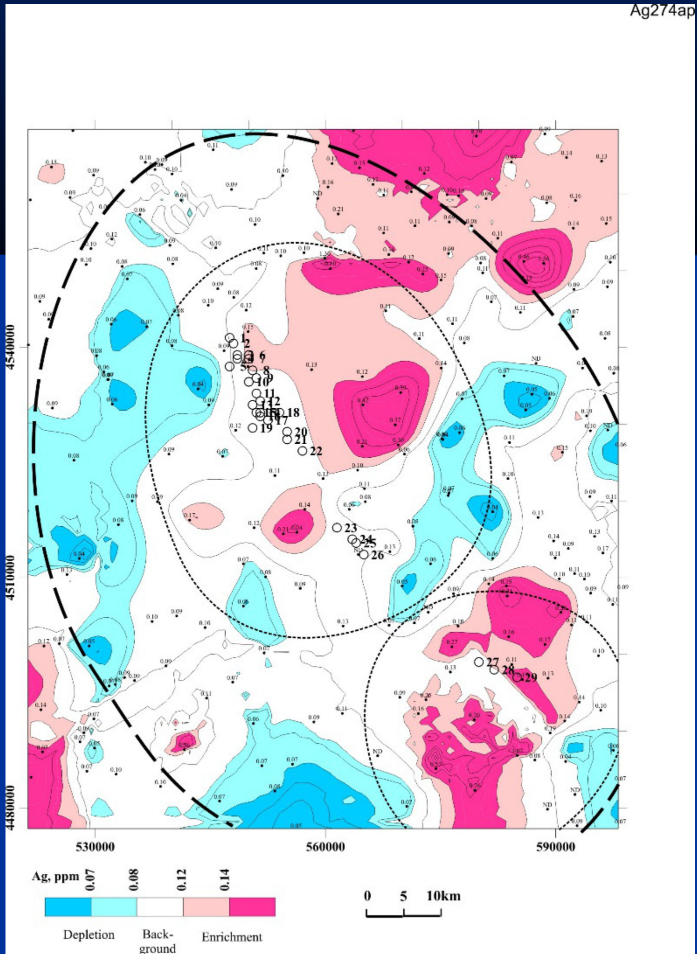
Cumulative distribution plot of As



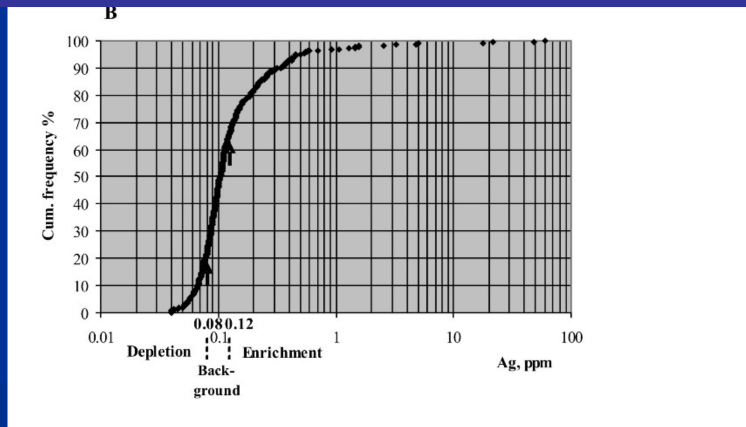
Enrichment zones of As -2320 sq km
Depletion zones As -2324 sq.km

CARLIN-TREND GOLD DEPOSITS
USA

Distribution of Ag

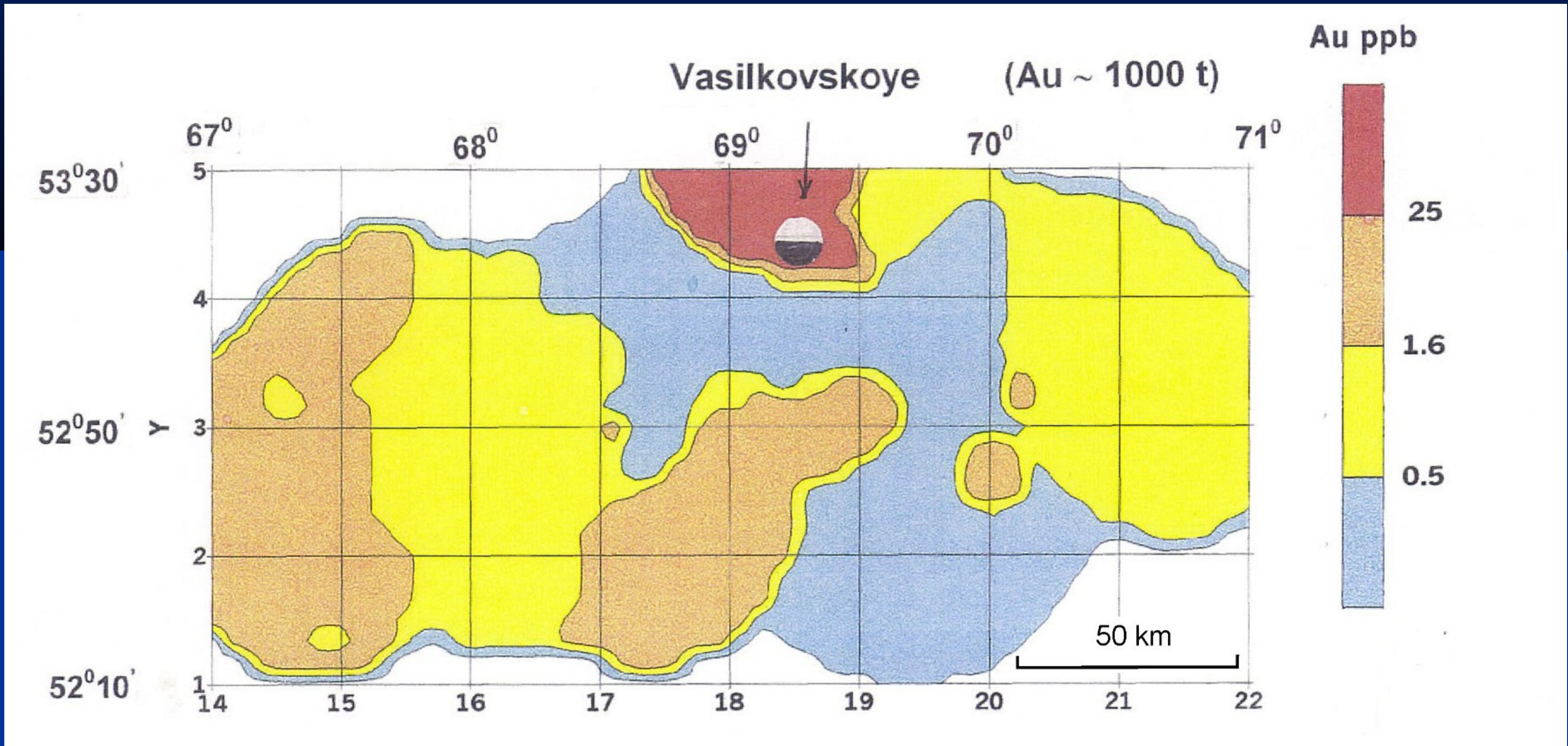


Cumulative distribution plot of Ag



Enrichment zones of Ag -1580 sq km
Depletion zones of Ag -2324 sq km

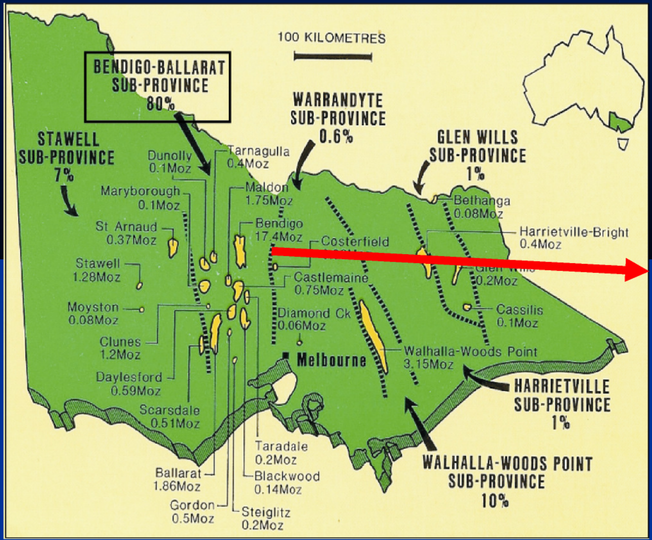
ORE REGION OF VASYLKOVSKOE GOLD PORPHYRY DEPOSIT NORTH KAZAHSTAN

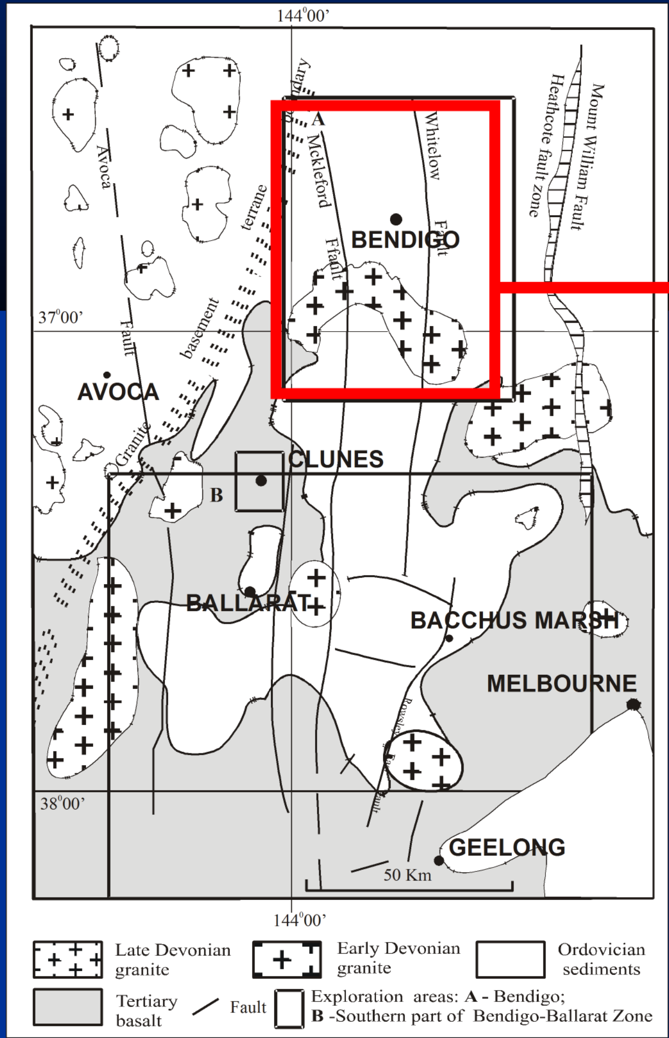


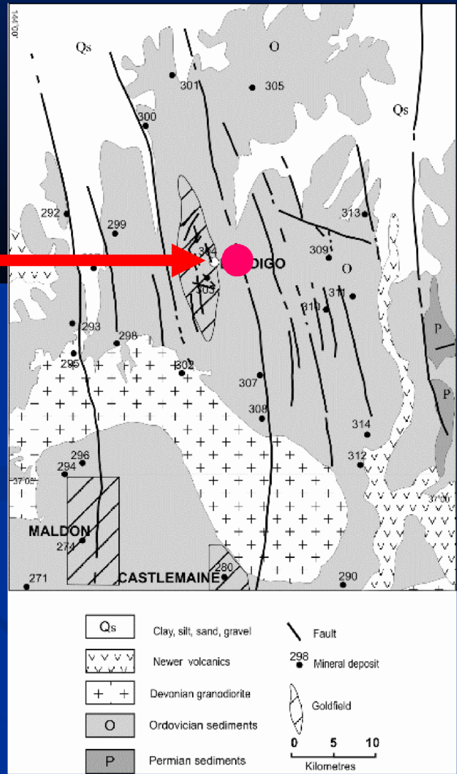
Area (S) 15 500 sq km
Number of samples - 1100
Detection limit of Au – 0.2ppb
After rafalovich and Los 2007)

Enrichment zones (> 25 ppb) S = 800 sq km
Depletion zones (< 0.5 ppb) S = 4500 sq km
Background 1.5 -2 ppb

BENDIGO-BALLARAT GOLD PROVINCE





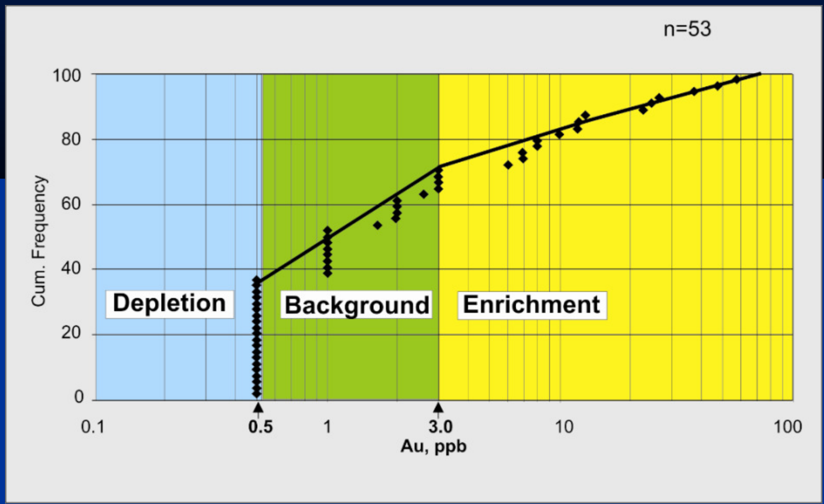


Geological map of Bendigo gold field

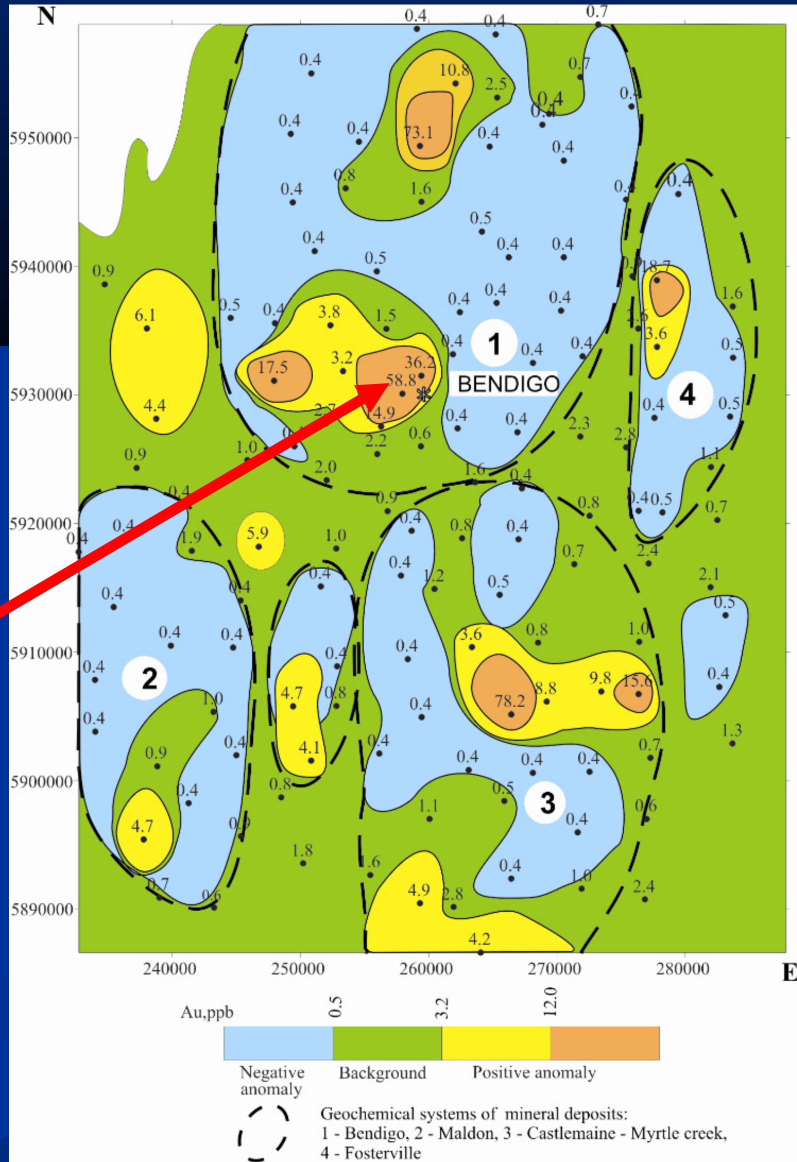
Area – 4000 sq.km.
Scale 1:500 000,
Density rock sampling - 1s/25 km.
134 rock samples.

GEOCHEMICAL SYSTEMS OF BENDIGO GOLD FIELD

Cumulative distribution plot of Au



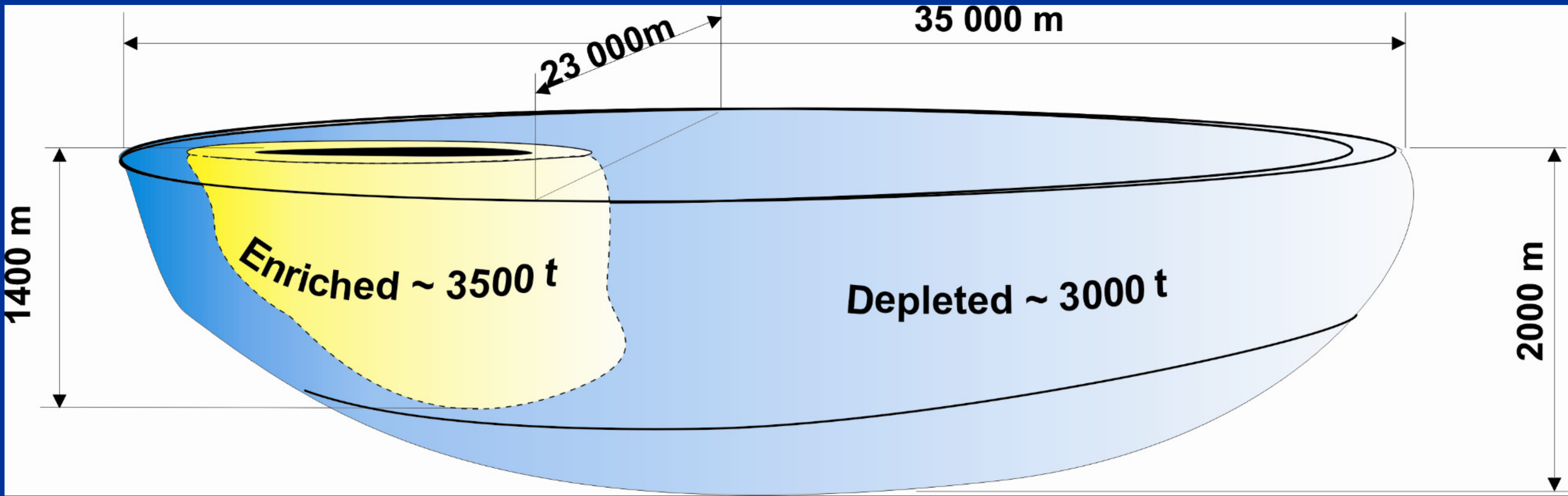
Analysis at ALS Chemex. Brisbane



GEOCHEMICAL SYSTEMS:
1.BENDIGO 2.МАЛДОН
3.CASTEMAINE 4. FOSTERWILL

MASS BALANCE CALCULATION OF GOLD

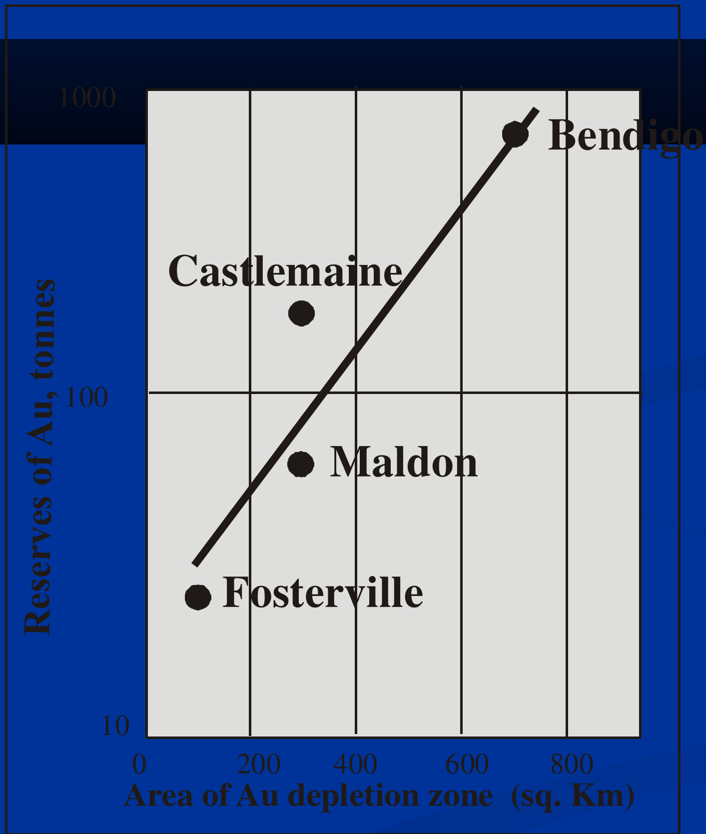
Zones	S, km^2	H_{depth}, km	V, km^3	$Au_{average}$, ppb	Au_{enrich}, ppb	Au_{loss}, ppb	R, t
Enrichment zone	100	1.4	100	14	12.71		~3500
Background				1.29			
Depletion zone	800	2	1600	0.5		0.79	~3000



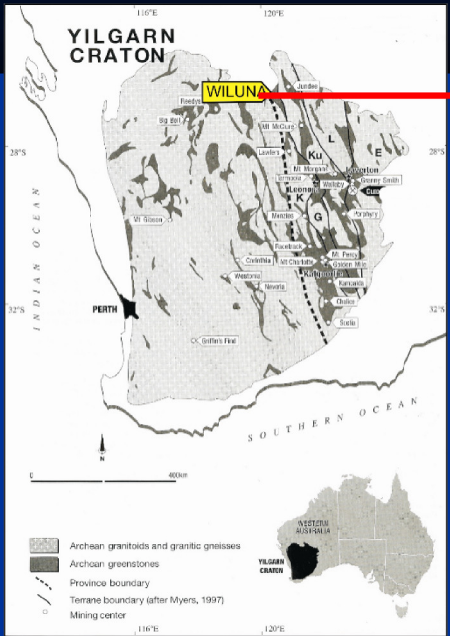
Model of geochemical system of Bendigo gold deposit

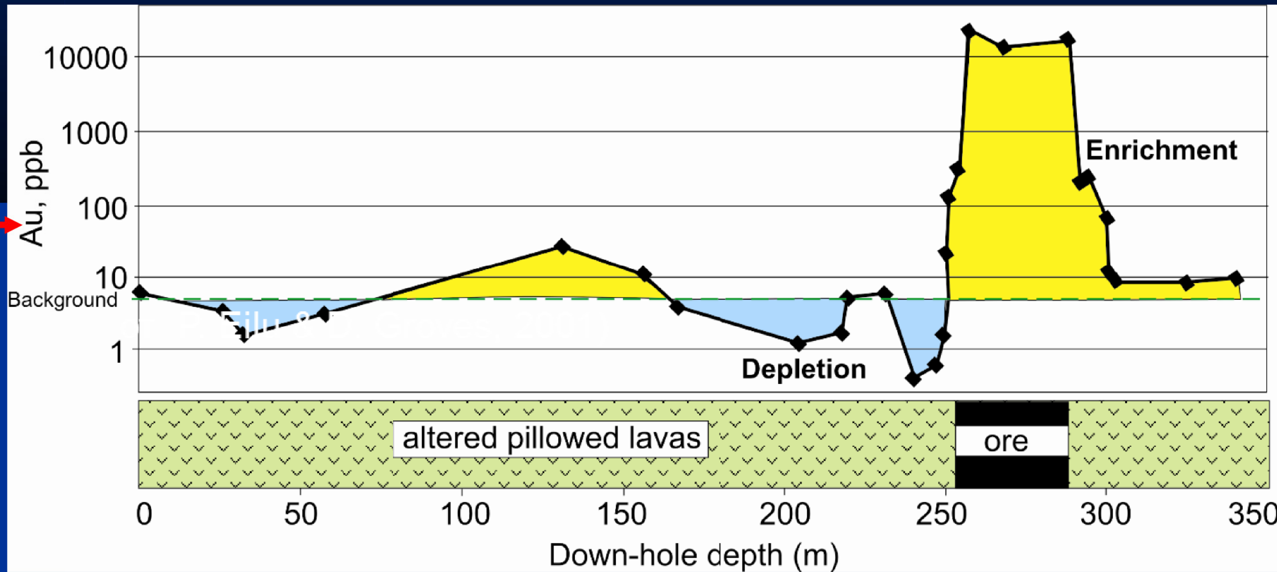
THE CRITERIA APPRAISING FAVOURABLE AREAS

- The link between the size of Au depletion zones and Au reserves in the gold deposits of the Bendigo region



Wiluna Archaean orogenic gold deposit. Northernmost Norseman-Wiluna Belt in the Yilgarn Craton, Australia



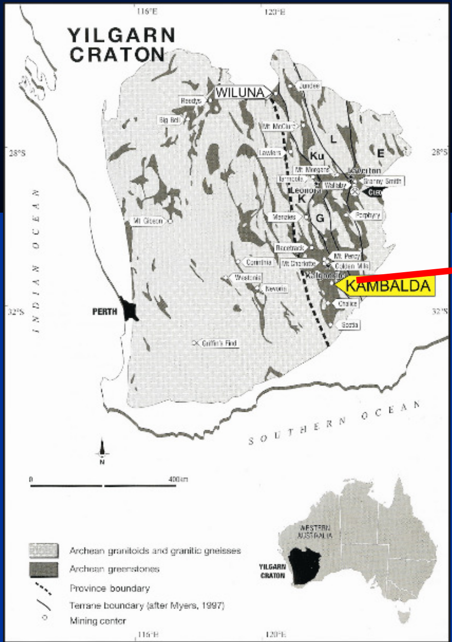


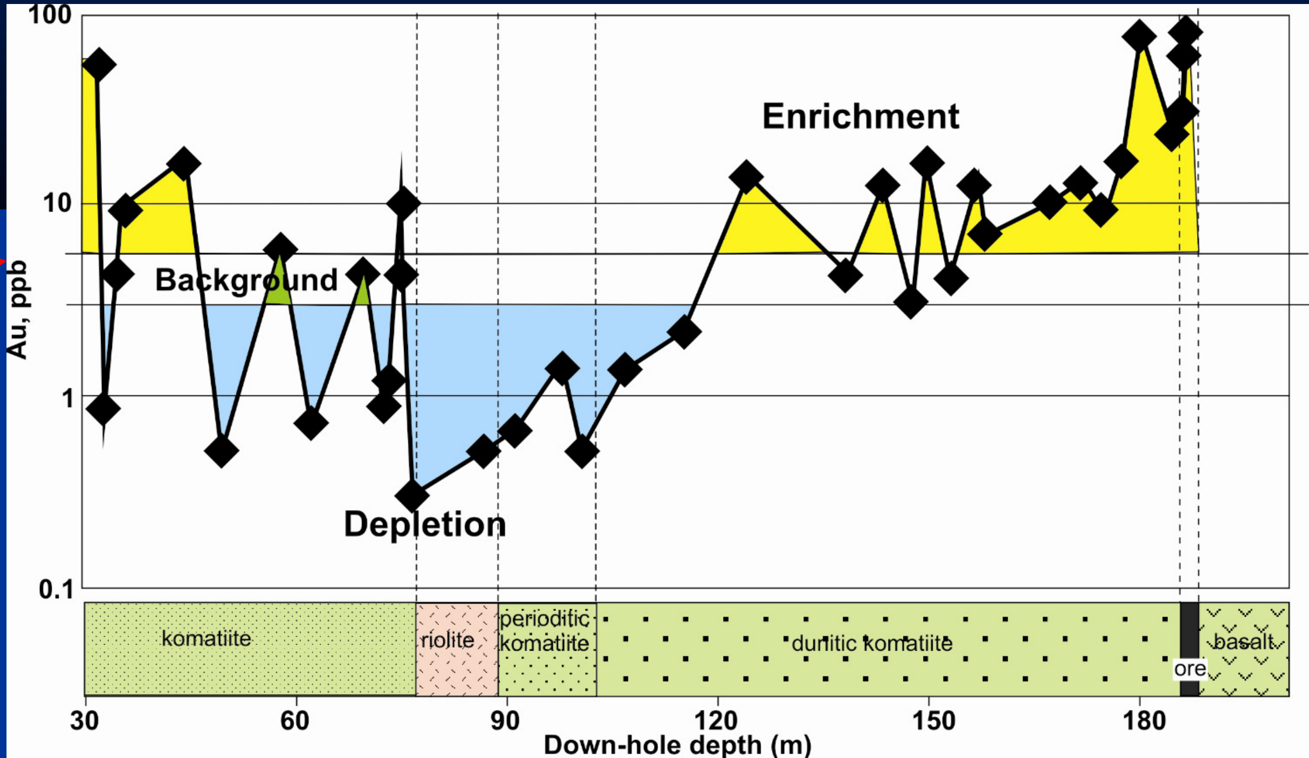
Distribution of Au in drill core

After P. Eilu & D. Groves, 2001

Western Australia

Ni-Cu deposit Kambalda Norseman-Wiluna Belt the Yilgarn Craton, Australia





Western

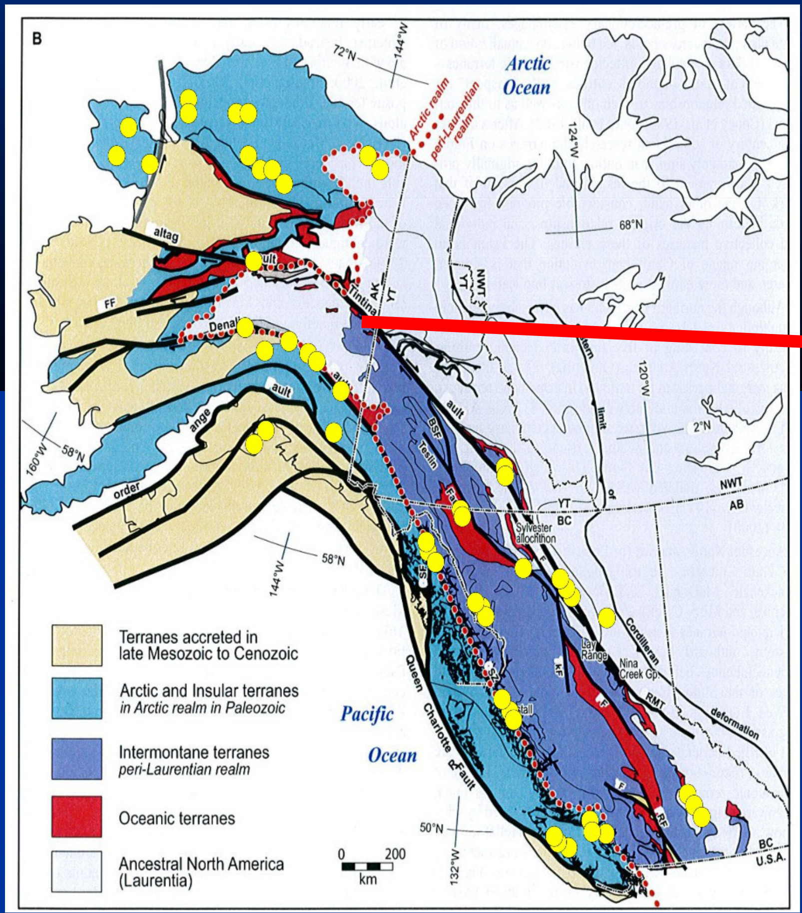
Australia

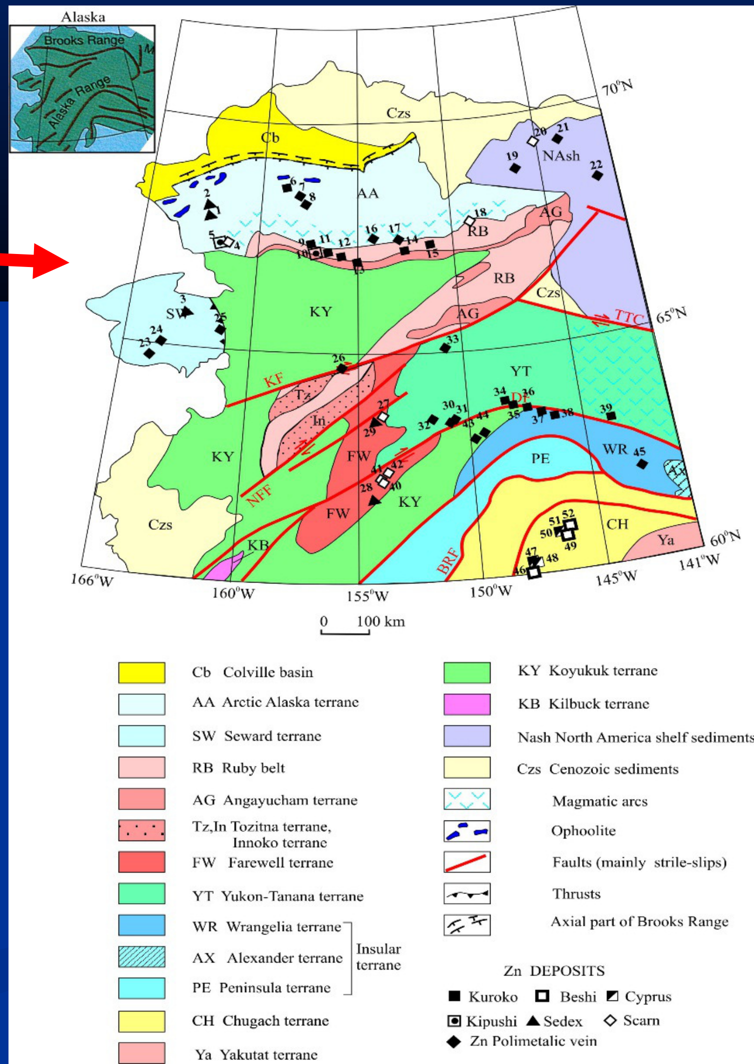
Distribution of Au in drill core

AfterRaid R. Keays, 1982)

NORTH –AMERICAN CORDILLERA

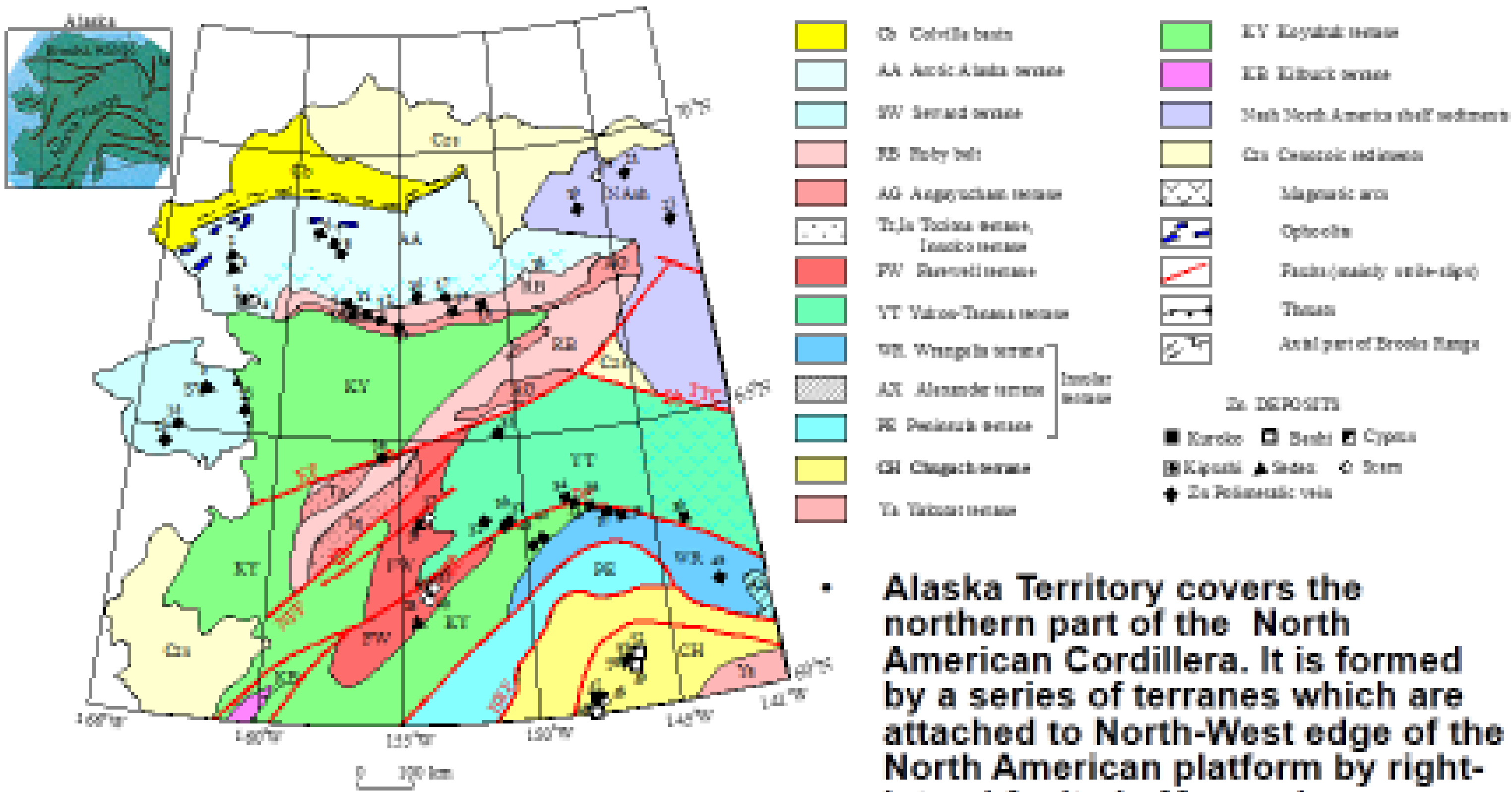
Geological map of Alaska





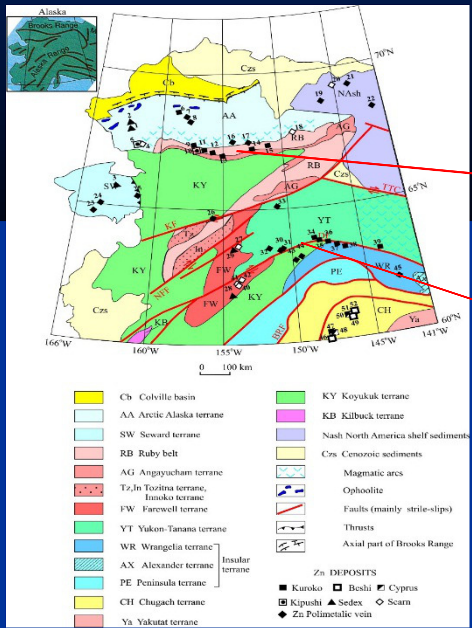
The Alaska Zn deposits are located within a metallogenic belt extending along North – American Cordillera.

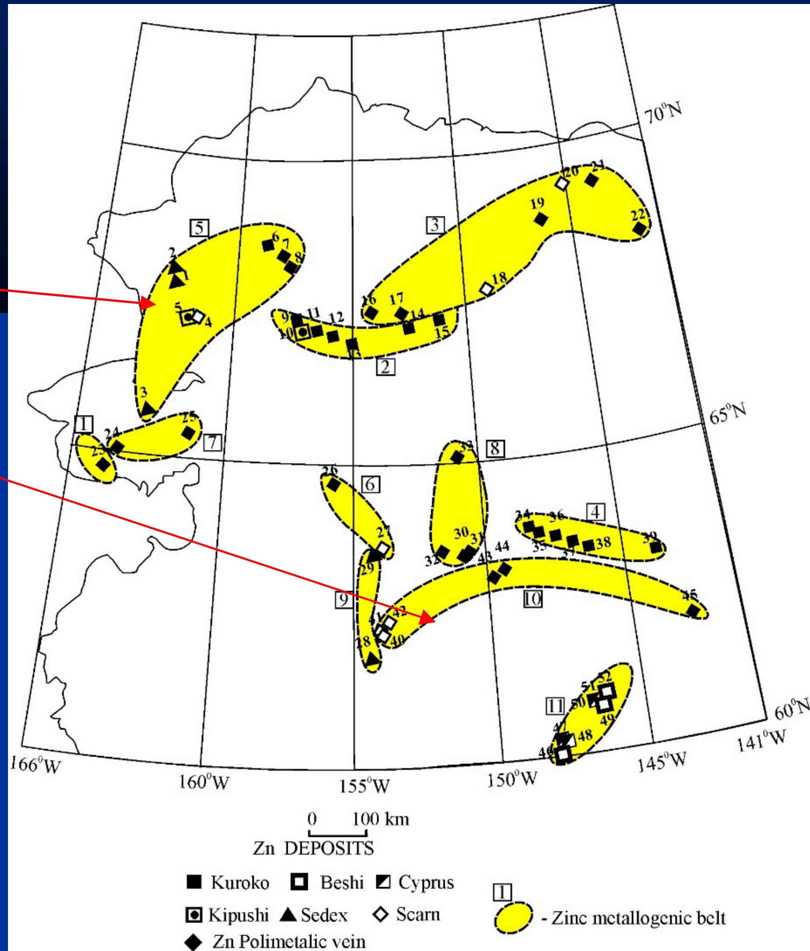
GEOLOGY



- **Alaska Territory covers the northern part of the North American Cordillera. It is formed by a series of terranes which are attached to North-West edge of the North American platform by right-lateral faults in Mesozoic**

ALASKA. Zn DEPOSITS

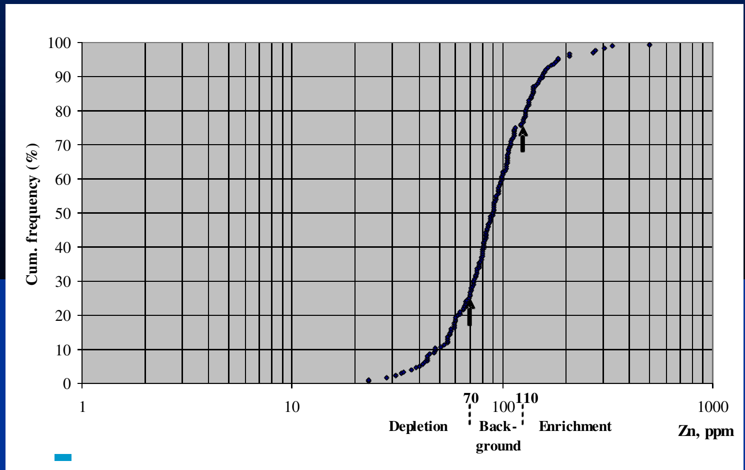




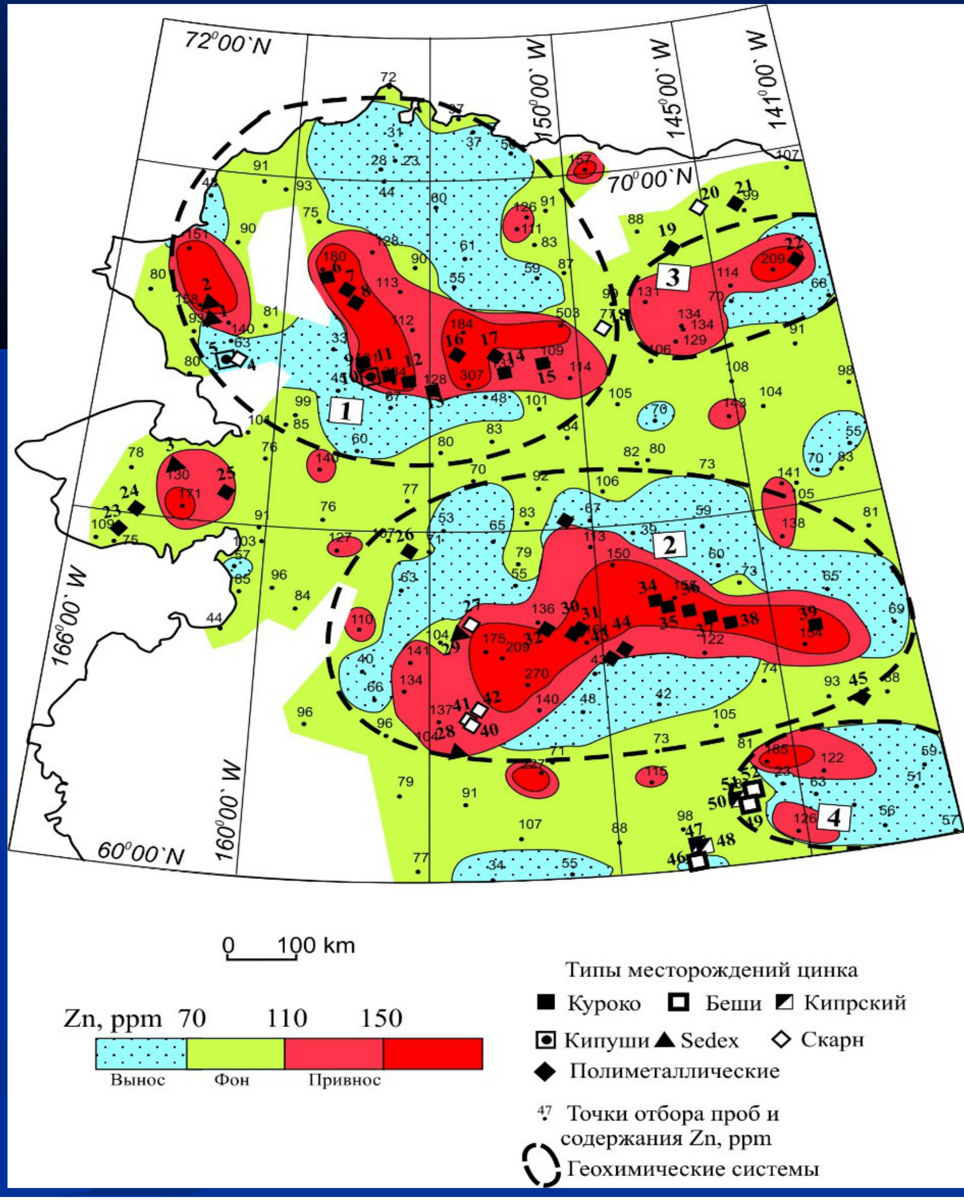
- On data of American geologists of USGS (Nokleberg et al., 1971 ; Nokleberg et al., 1972) different types of Alaska zinc deposits are combined into eleven metallogenic belts in accordance with their geodynamic and geological setting

Metallogenic belts (after W. Nokkleberg 1997

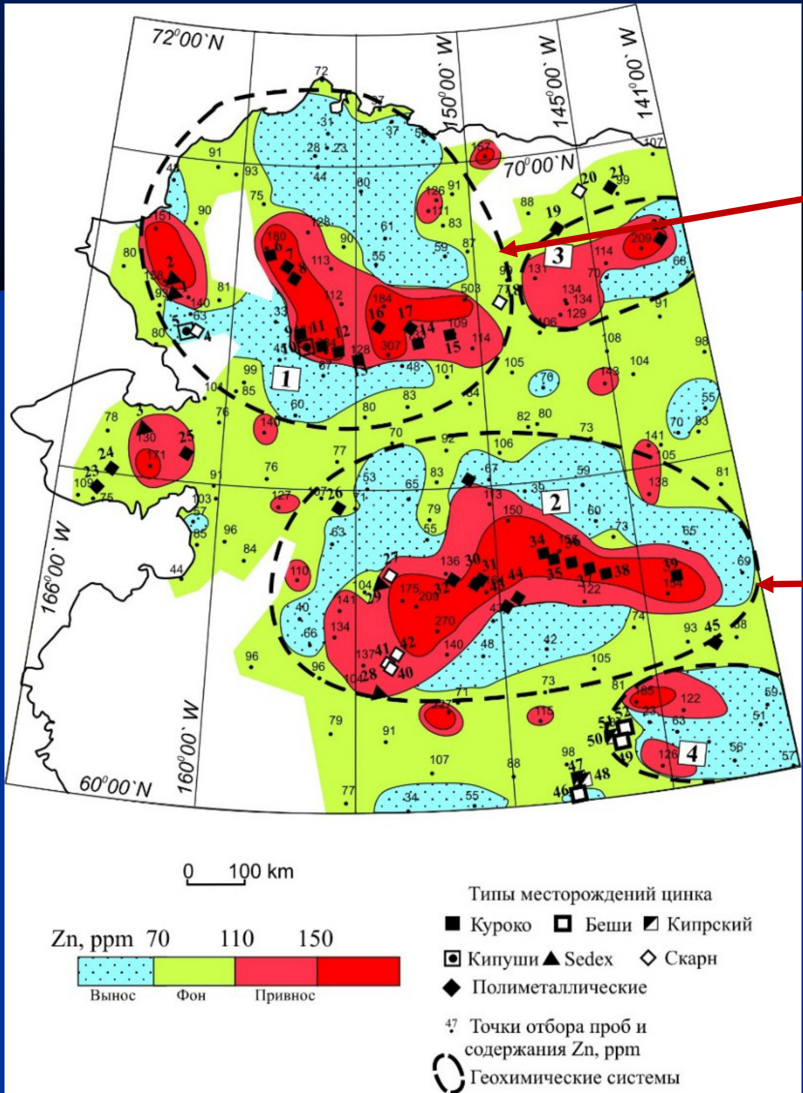
DISTRIBUTION OF ZINK. ALASKA



Cumulative distribution plot of Zn. 175 samples (1s/5000 sq/km), USGS Open-File Report 02-223-G 1991. Briggs P.H.



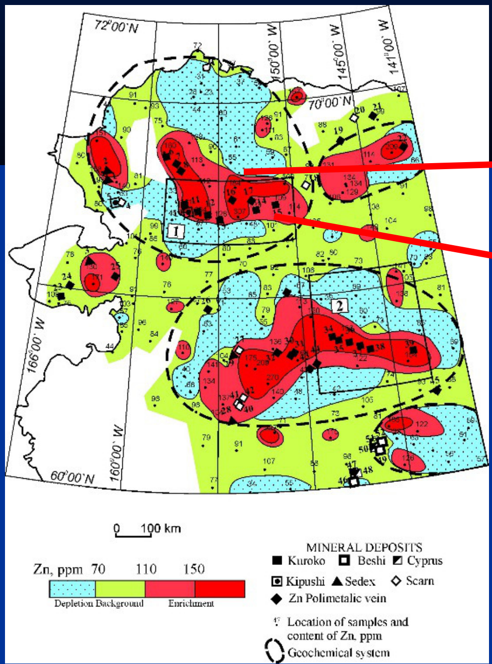
DISTRIBUTION OF ZINK. ALASKA

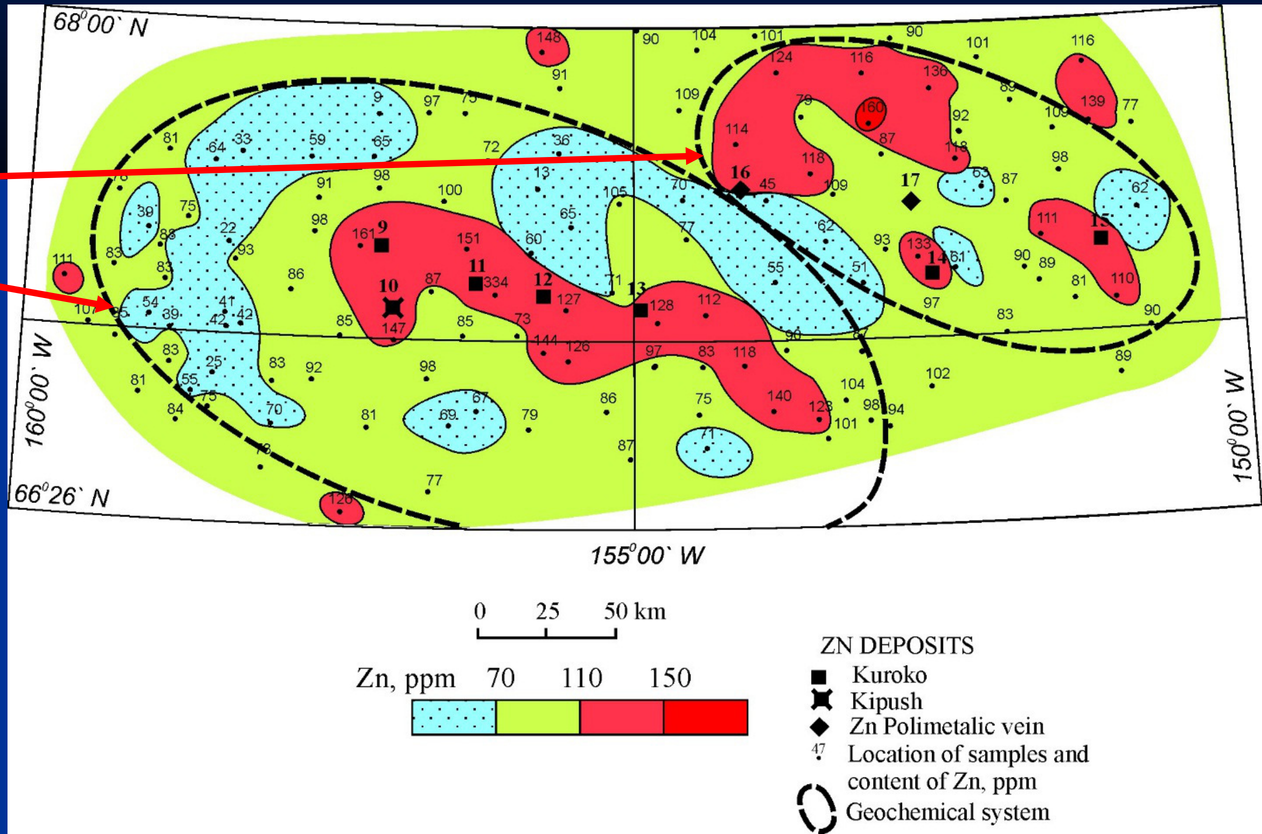


Northern geochemical system
(along Bruks Rahge)
Enrichment zone – 110,000 sq km
Depletion zone – 130,000 sq km

Central Geochemical system
(along Alaska Range)
Enrichment zone – 110,000 sq km
Deplition zone – 91,000 sq km

DISTRIBUTION OF ZINK IN THE NORTHENR CHEOCHEMICAL PROVINCE

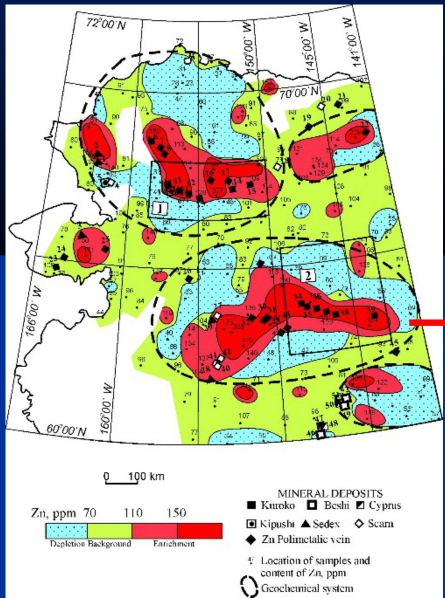


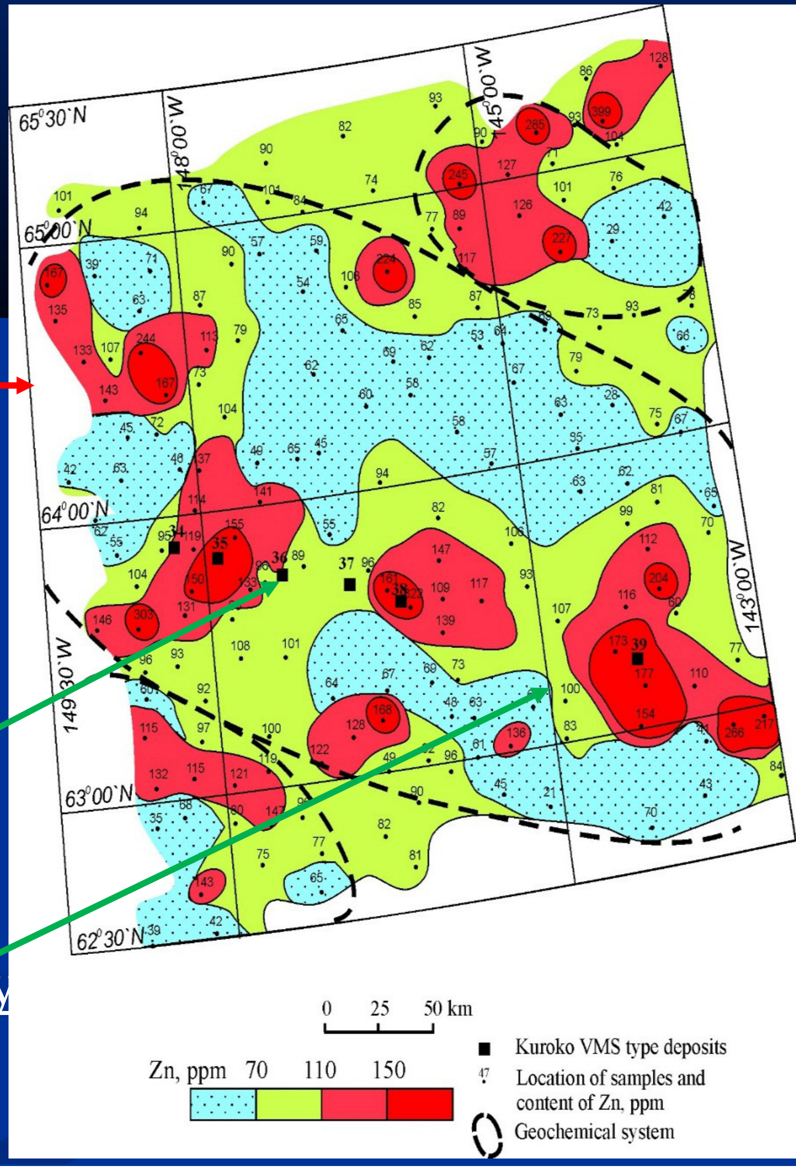


Geochemical systems of ore region scale

1.Ruby Creek 2. Michigan Creek

DISTRIBUTION OF ZINK IN THE CENTRAL GHEOCHEMICAL PROVINCE





Geochemical systems of ore region scale

1.WTF, Red Maunt,

2. Delta District (26 VMS Kuroko ty

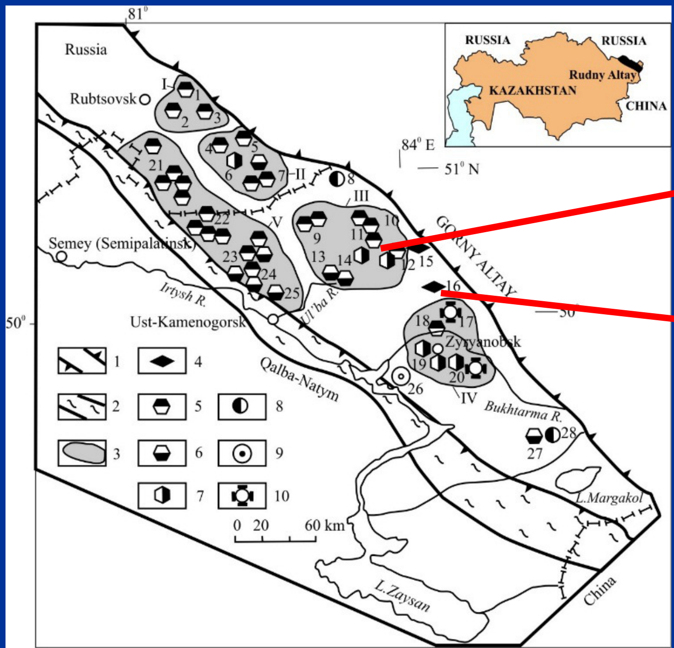
of deposits)

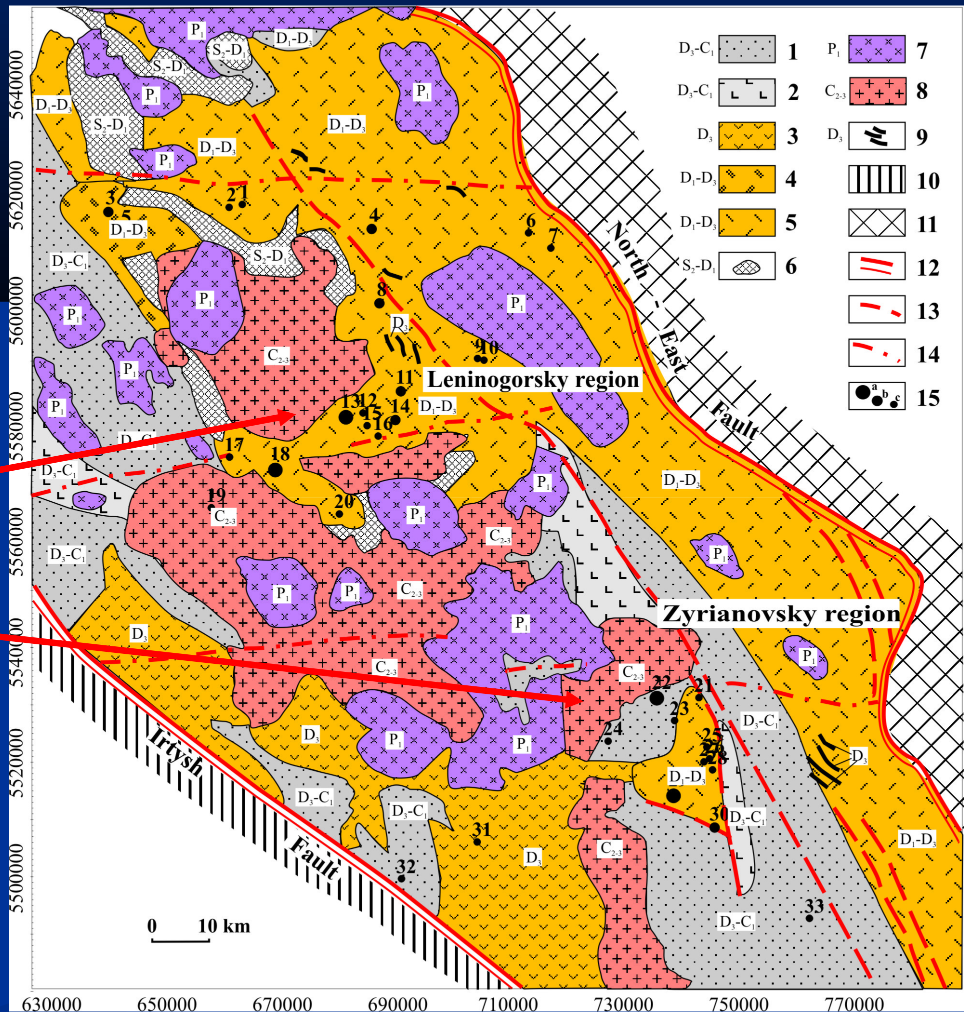
MASS-BALANS CALCULATION OF Zn IN CENTRAL GEOCHEMICAL SYSTEM OF ALASKA

Zones	Average ppm	Average Enrich/ Loss ppm (Background 89 ppm)	Degree of Enrich/Loss %	Enrich//Loss Gramm/m³	Volume of Enrich/Loss To 1 m depth km²	Enrich/Loss To 1 m depth M ton
Enrich-ment	159	70	78.6	175.7	101 000	18.5
Deple-tion	52	37	41.5	92.5	91 000	8.3

- Deficit of zinc in the depletion zone (91 000 sq km) on 1 m of depth is 8.3 million tons, and the accumulation of Zn in the enrichment zone (110 000 sq km) is 18.5 million ton, respectively.
- Therefore, the depletion zones can be consider as the areas of mobilization.

RUDNY ALTAY METALLOGENIC PROVINCE
KAZAKHSTAN
VMS DEPOSITS





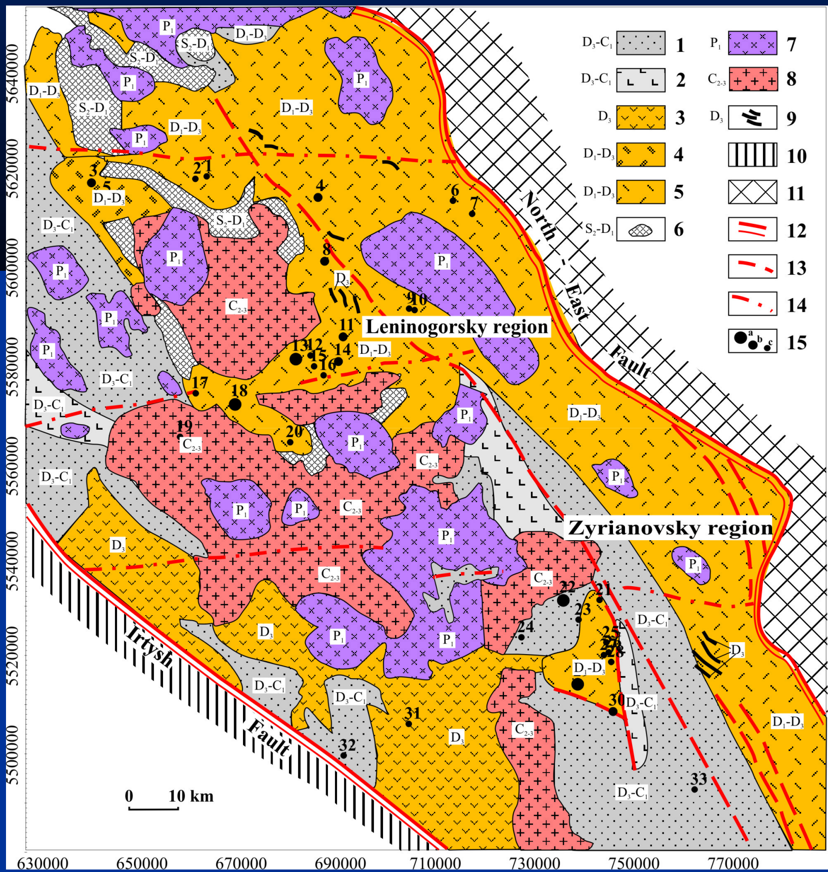
Geological map of Leninogorsky and Zyryanovsky ore regions (20 000 sq km)

GEOLOGICAL MAP OF LENINOGORSK AND ZYRYANOVSK REGION

Down to depth of ~10 km the regions have a two-layer structure:

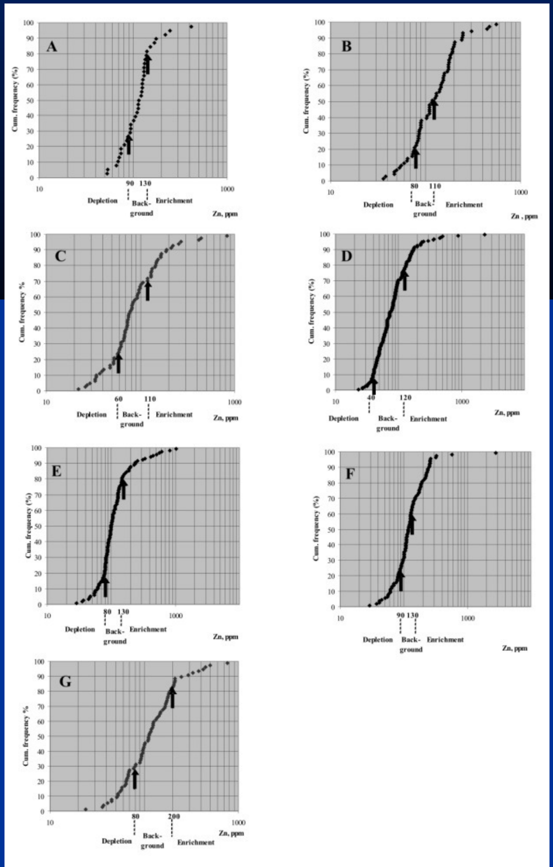
S_2-D_1 layer – sandstone, phyllites and greenschist

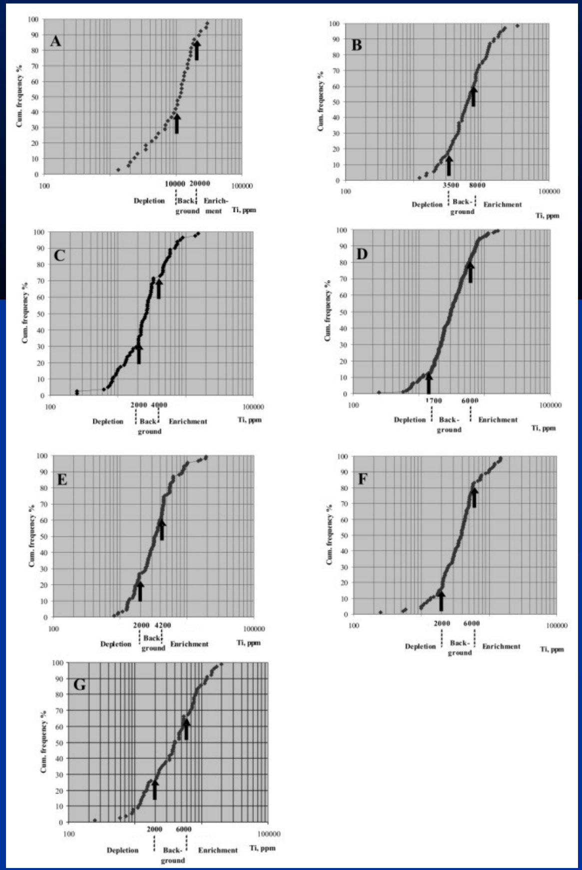
D_1-D_3 layer – volcanogenic–sedimentary formations with main VMS mineralization.



Area – 20 000 sq.km. 1s/25 sq.km. 800 rock samples.

Distribution of Zn & Ti in Different Rocks of Leninogorsky and Zyryanovsky Regions





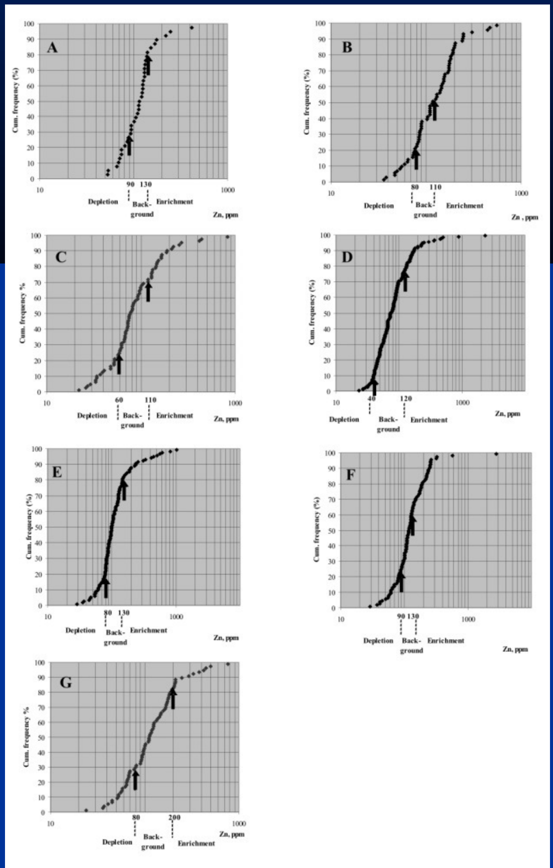
Cumulative plotss of Zn and Ti distribution in rocks of Leninogorsky and Zyryanovsky ore regions of Rudny Altay. Kazakhstan. A) Gabbro – diorite. B) Andesite – basalt. C) dacite – rhyolite. D) Granitoids. E) Sandstone. F) Shale. G) Hornstone

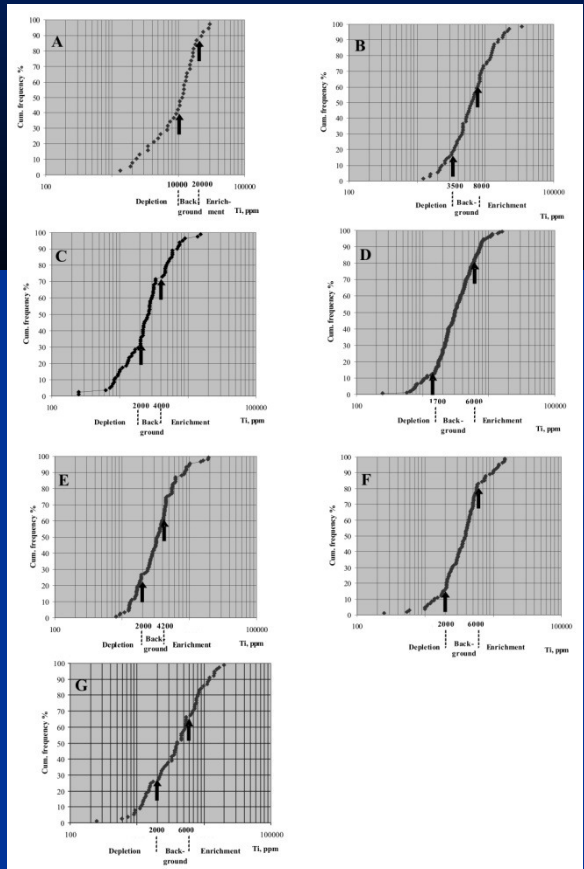
On the base of petrographic study area there are seven main types of rock : gabbro – diorite, andesite – basalt, dacite – rhyolite, granitoids, sandstone, shale and hornstone.

For each of the rock types the cumulative distribution plots of zinc and titanium were made

.

Distribution of Zn & Ti in Different Rocks of Leninogorsky and Zyryanovsky Regions



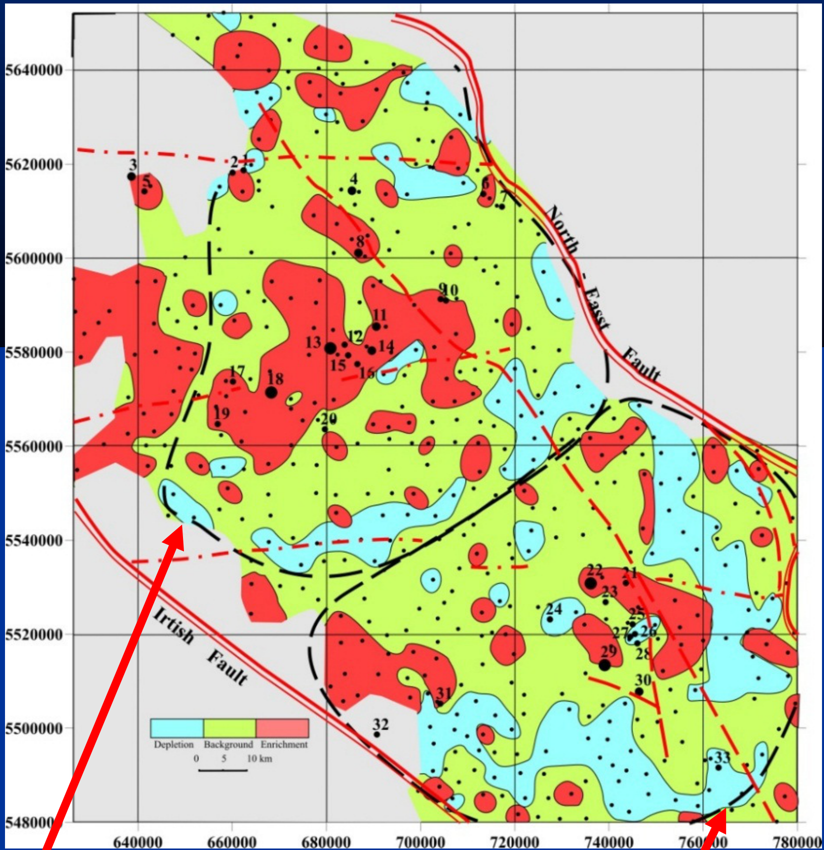


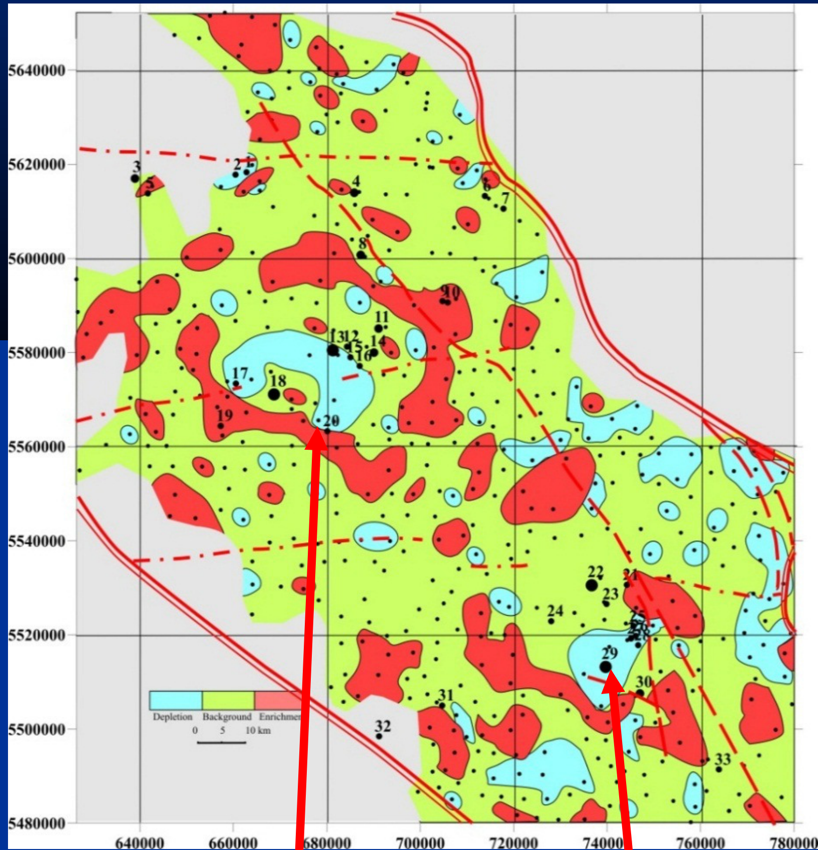
There are three populations: medium – background, tops - enrichment anomaly, bottom – depletion anomaly.

Due to the great variety of rock composition the metal concentrations in each sample were normalized to their backgrounds. The boundaries of anomalies and backgrounds were drown according to this data.

Cumulative plotss of Zn and Ti distribution in rocks of Leninogorsky and Zyryanovsky ore regions of Rudny Altay. Kazakhstan. A) Gabbro – diorite. B) Andesite – basalt. C) dacite – rhyolite. D) Granitoids. E) Sandstone. F) Shale. G) Hornstone

DISTRIBUTION OF Zn AND Ti IN LENINOGORSKY AND ZYRYANODSKY ORE REGIONS

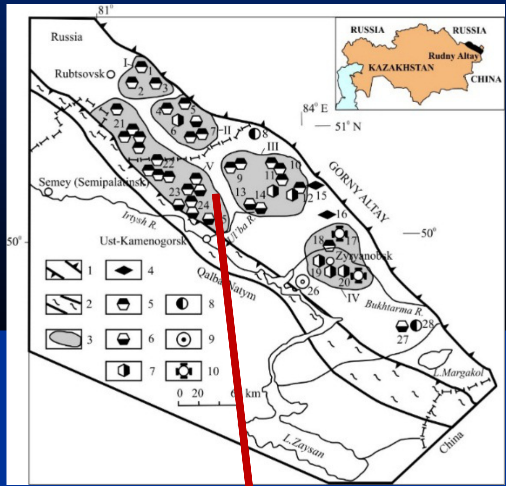


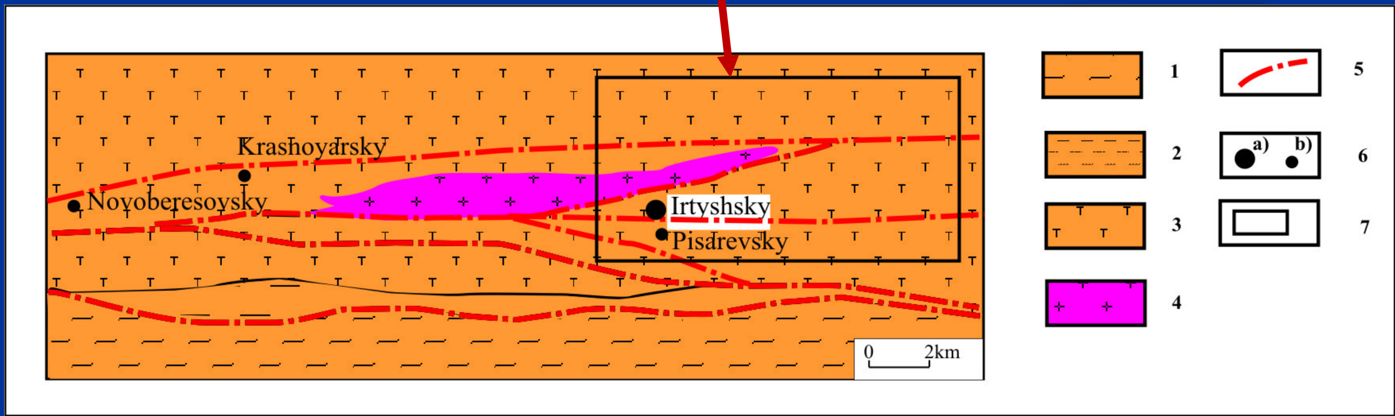


Leninogorsky geochemical system
Enrichment zone -1200 sq km
Depletion zone –1000 sq km
Zyryanovsky geochemical system
Enrichment zone -1500 sq km
Depletion zone –1250 sq km

Nucleous parts of systems

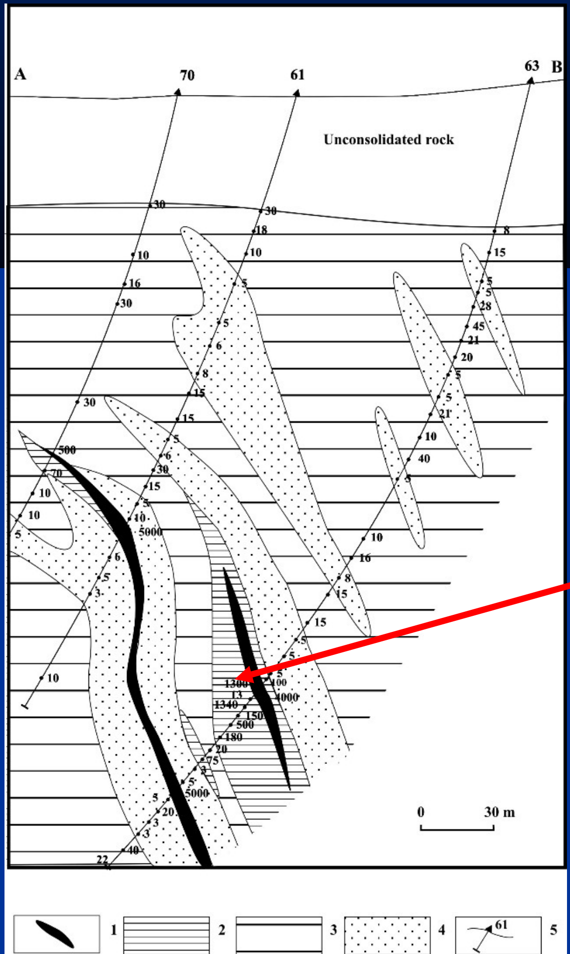
IRTYSHSKY VMS DEPOSITS in RUDNY ALTAY METALLOGENIC PROVINCE. KAZAKHSTAN





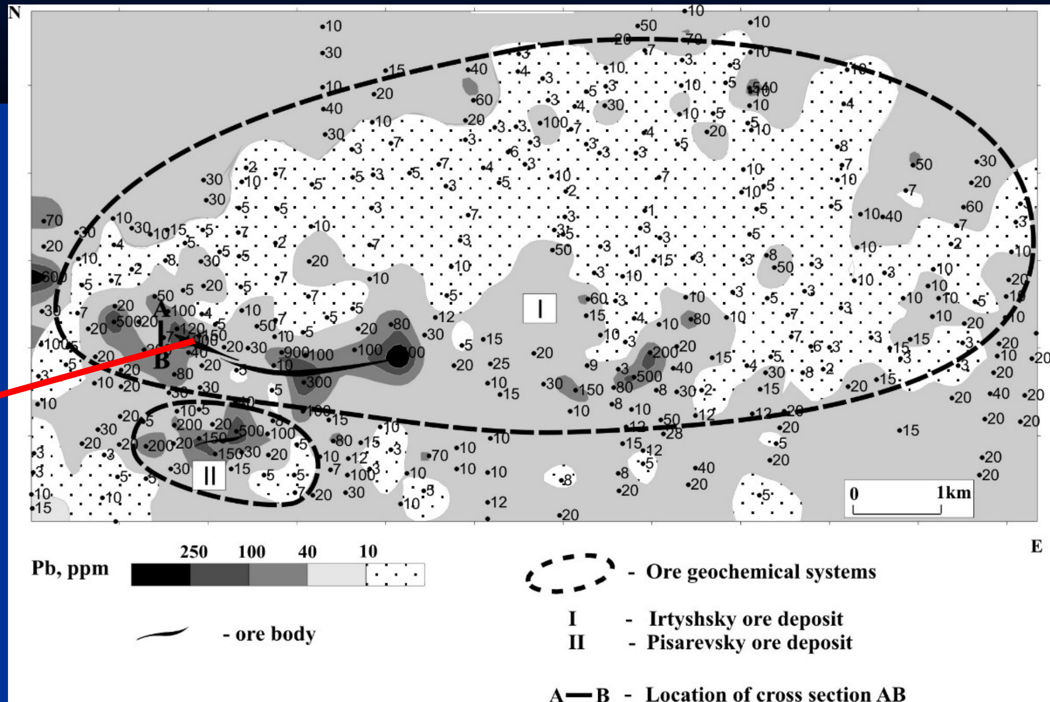
Simplified geological map

IRTYSHSKY VMS DEPOSITS
RUDNY ALTAY. KAZAKHSTAN

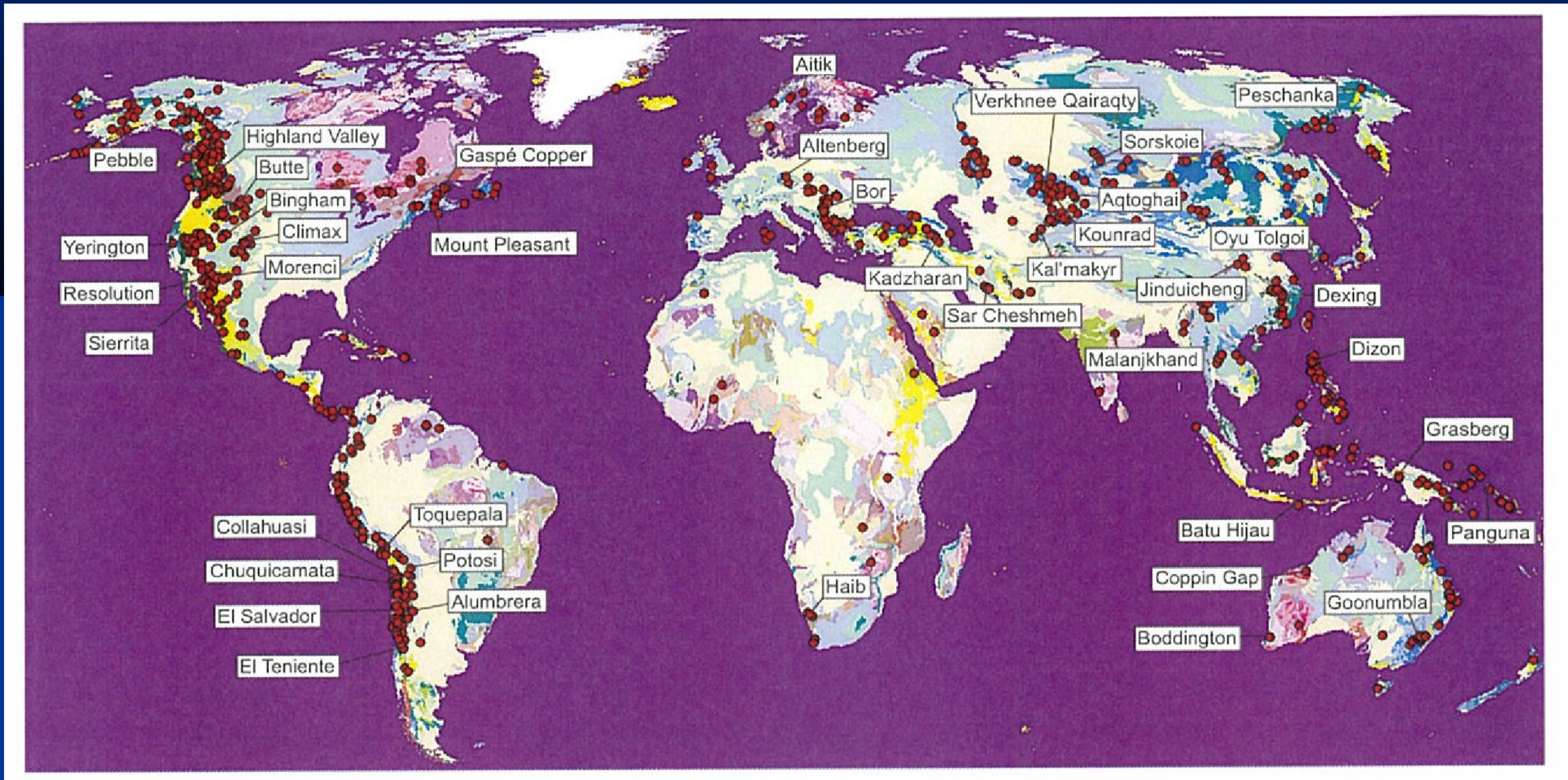


Cross-section A-B

DISTRIBUTION OF Pb



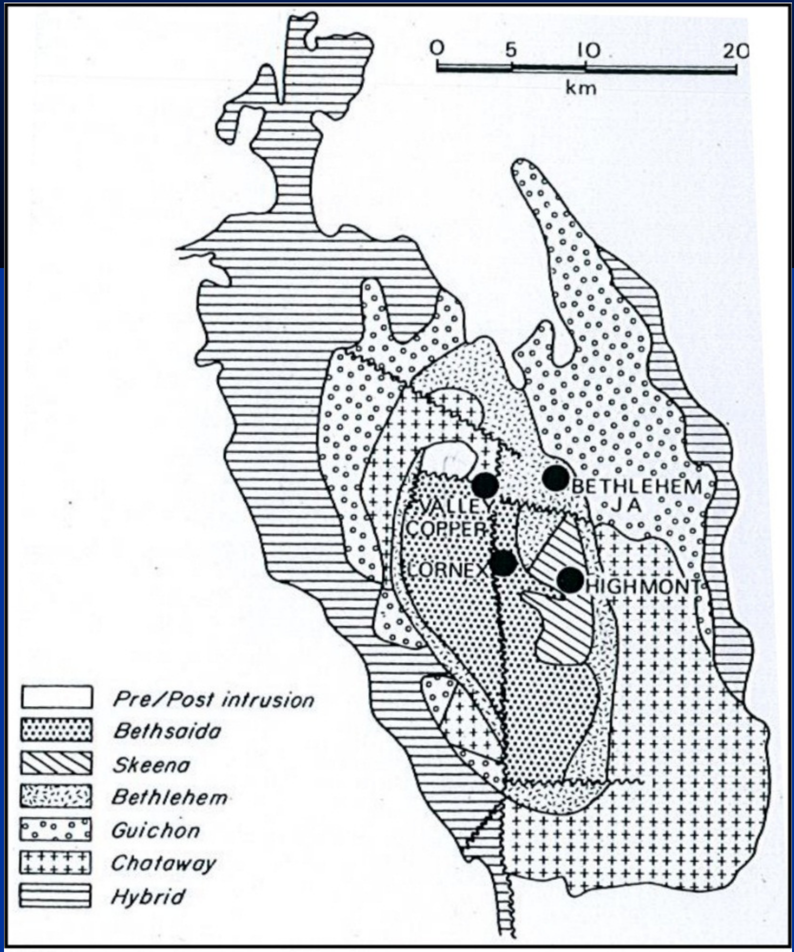
Cu PORPHYRY DEPOSITS



1. Highland (Canada) 2. Dexing (China) 3. Duoboshan (China).

(After W.D. Sinclair,2007)

Cu PORPHYRY DEPOSITS
Highland ore region (Canada)



Guichon Creek Batholit (Olade and Flether, 1976)

16 Cu-porphyry deposits hosted by Guichon Creek Batholit. The main deposits:

Valley Copper,

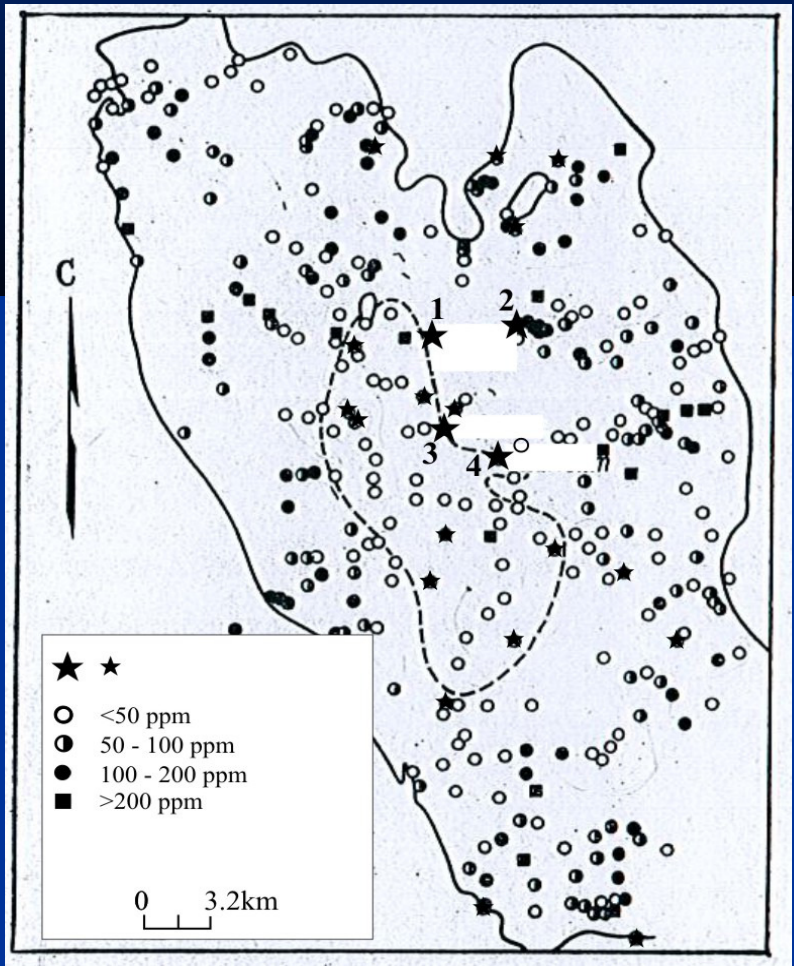
Lorenex, Higmont

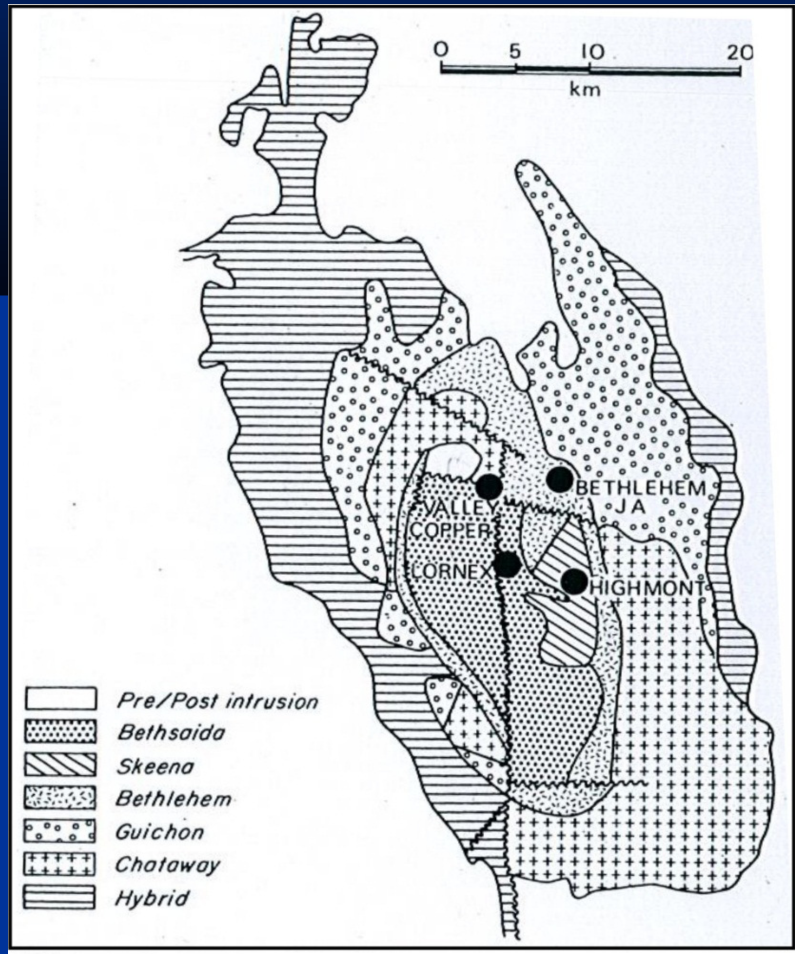
Bethlehem.

The total reserves:

8 Mt Cu (Cu 0.42%)

Cu PORPHYRY DEPOSITS
Highland ore region (Canada)





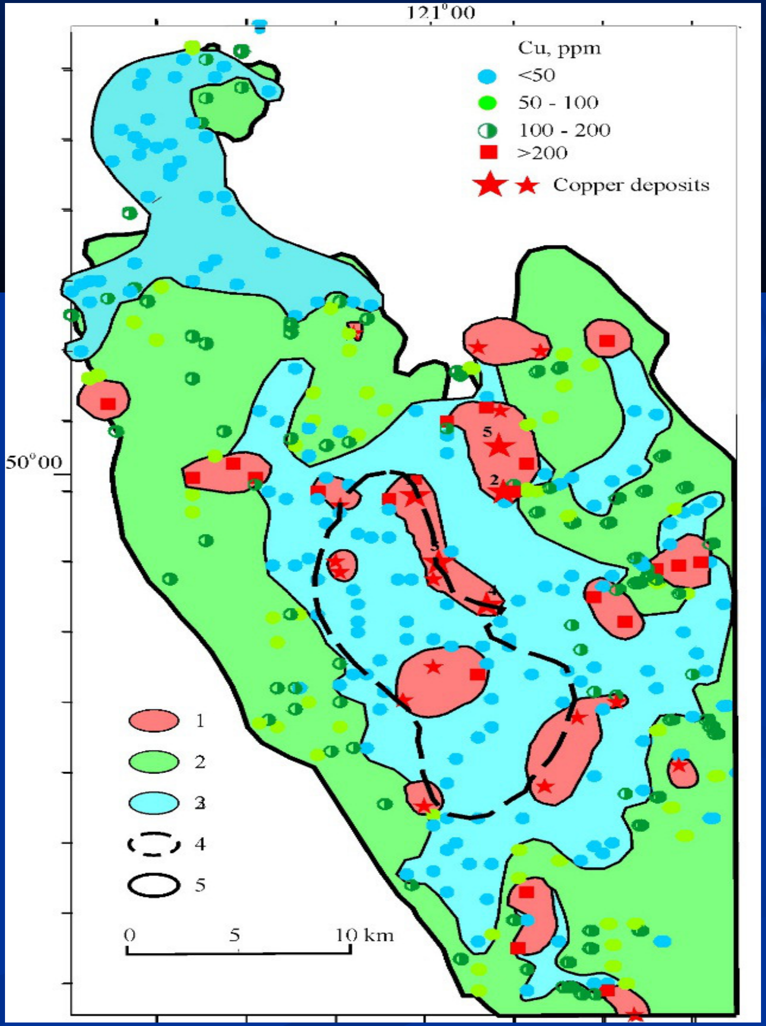
Distribution of Cu , 1500sq.km, 352 s. .
(After Brabec and White, 1971)

Guichon Creek Batholit
(Olade and Flether, 1976)

DISTRIBUTION OF Cu
Guichon Creek Batholit

Depletion zone < 50 ppm.

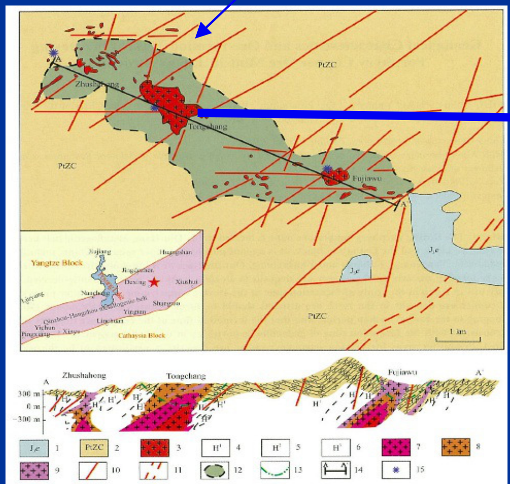
S - 820 sq km
Degree of Cu relies – 46%
Total deficit of Cu – 25 Mt
(250 m of depth)



(Modified after Brabes, 1971 G.Govett 1983)

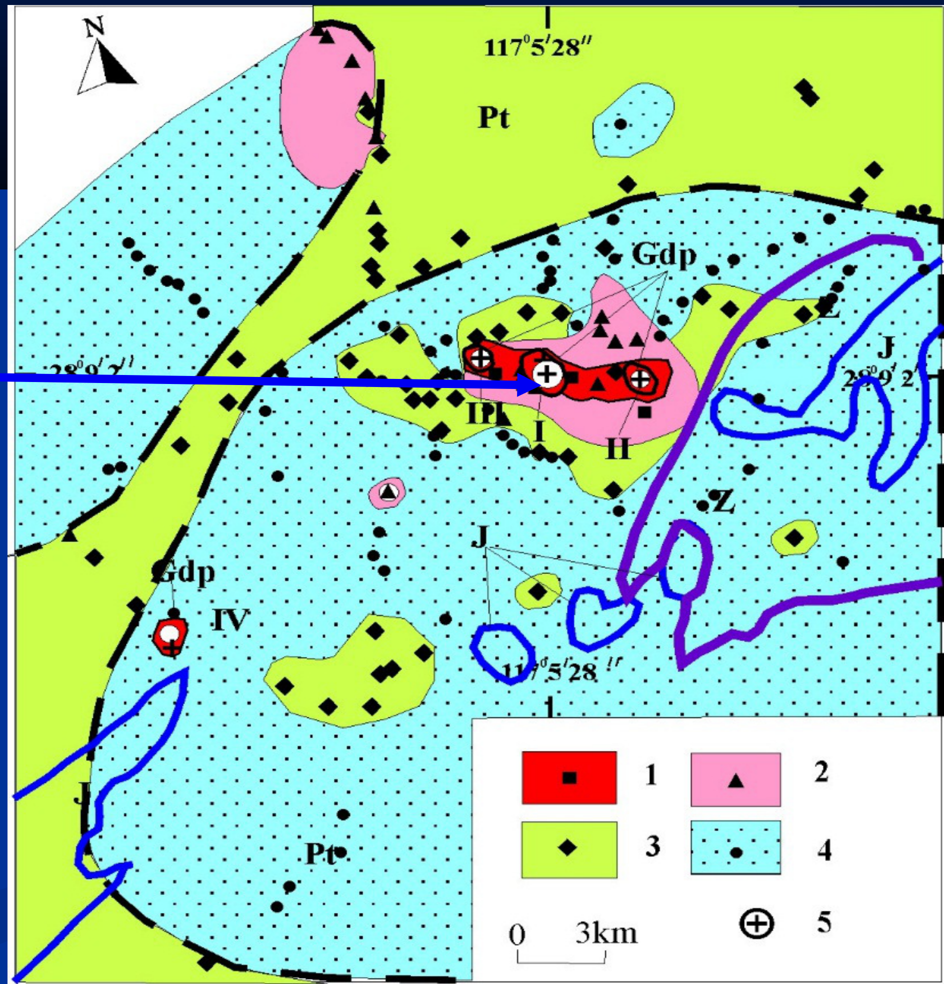
Cu PORPHYRY DEPOSITS
Dexing, SE China

Reserves of Tongchang deposit -5.2 Mt Cu, 190 t Au (Ji Kejian et al., 1992,)



Cu (ppm)
1..> 150. 2. 100 -150,
3 50-100 4. < 50
5. Deposits

Distribution of Cu



Cu PORPHYRY DEPOSITS
Dexing, SE China

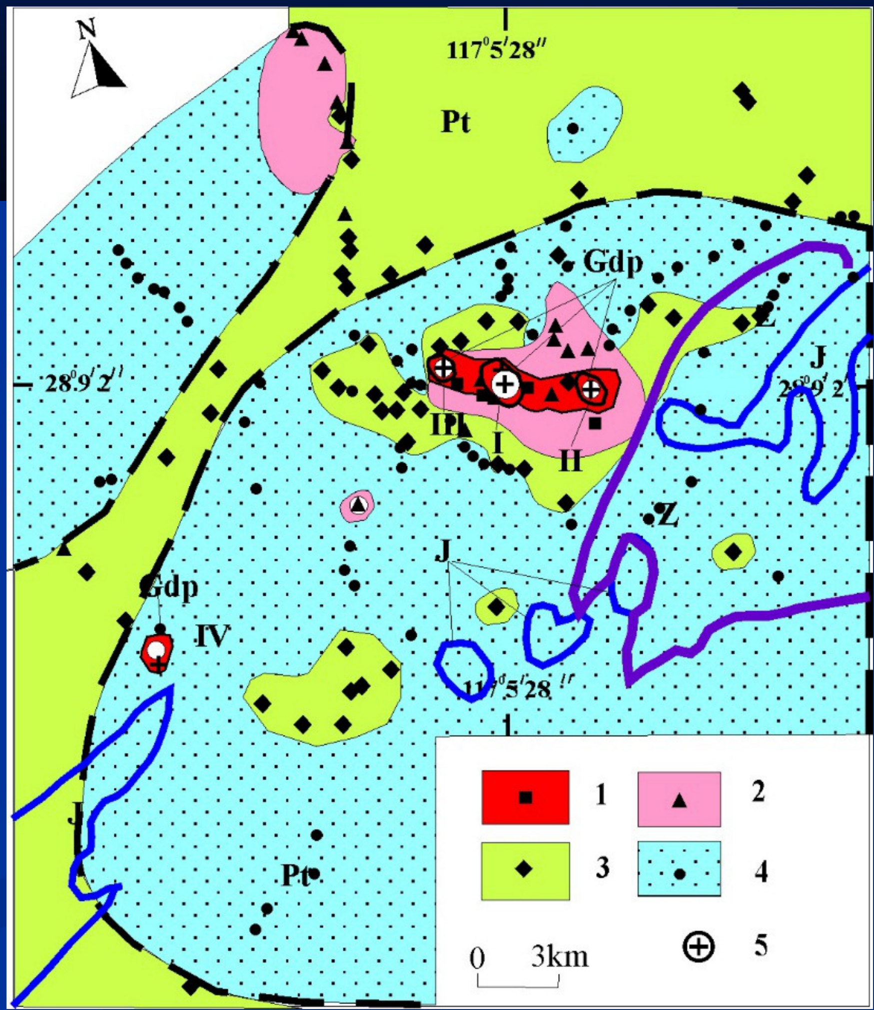
Reserves of Tongchang deposit -5.2 Mt Cu, 190 t Au

Cu (ppm)
1..> 150. 2. 100 -150,
3 50-100 4. < 50

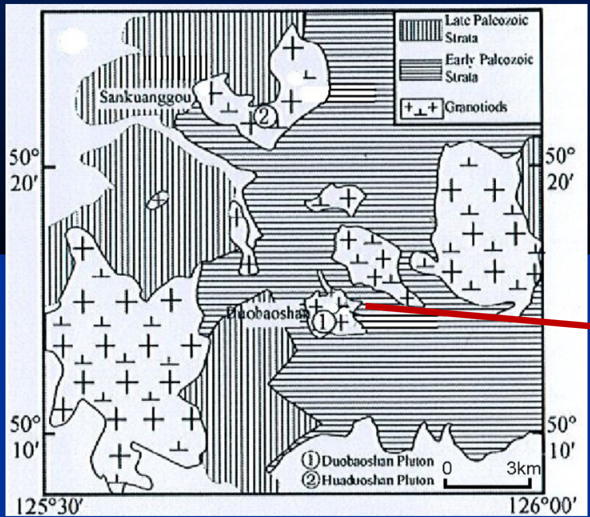
Enrichment zone - 40 sq km
Depletion zone – 480 sq km
Cu deficit – 15.4 Mt

(Estimated by 500 m of depth)
(Ji Kejian et al., 1992, 195 p)

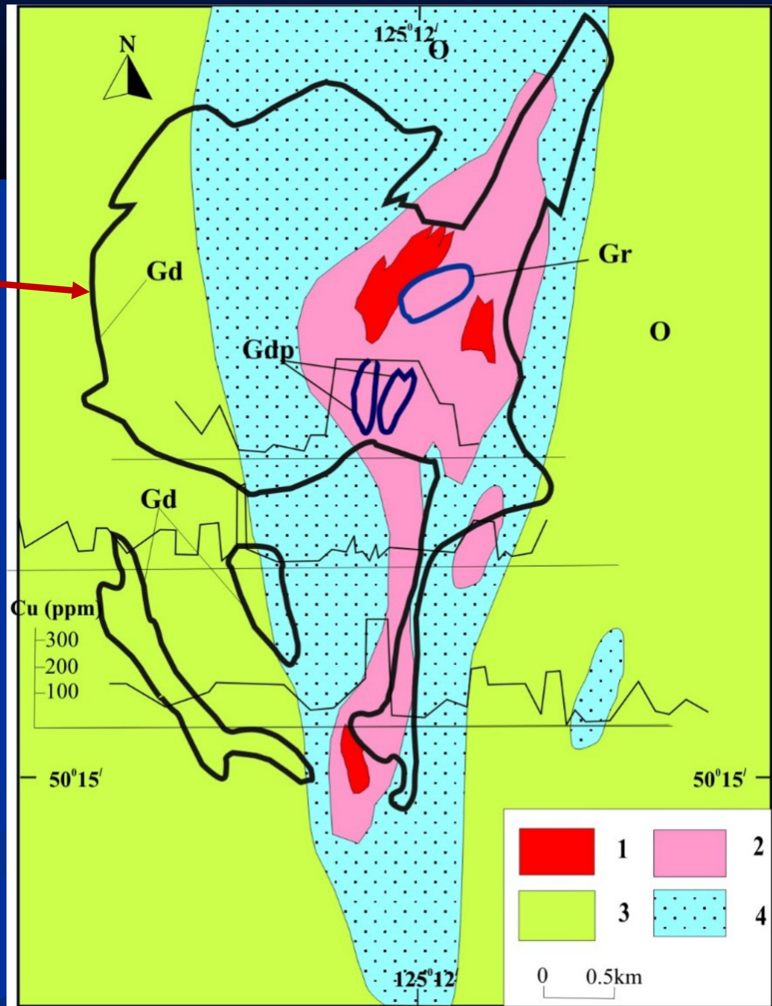
Распределение концентраций Cu



Cu PORPHYRY DEPOSITS
Duobaoshan, NE China



Distribution of Cu



O –Andesite
Gd - Granodiorite
Gr - Granite
Gdp – Granodiorte-porphyry

1. Cu-porphyry ore body
2. Enrichment zone of Cu >200 ppm.
3. Background - 200-70 ppm
4. Depletio zone Cu < 70ppm

* В числителе среднее содержание Cu в знаменателе количество проб.

Cu PORPHYRY DEPOSITS
Duobaoshan, NE China

Reserves

2.4 Mt Cu, 73 t Au

Enrichment zone 3.6 sq km.

Depletion zone 15 sq km.

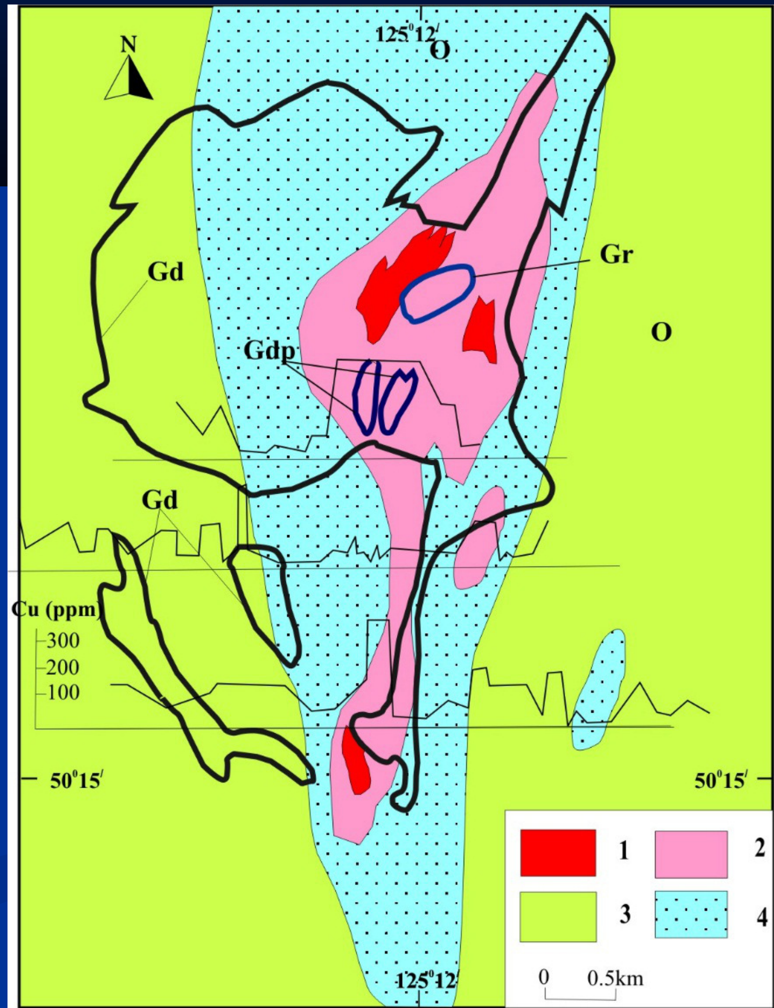
Enriched of Cu - 1.3 Mt

Deficit of Cu - 3.4 Mt

(Estimated by 1 km of depth)

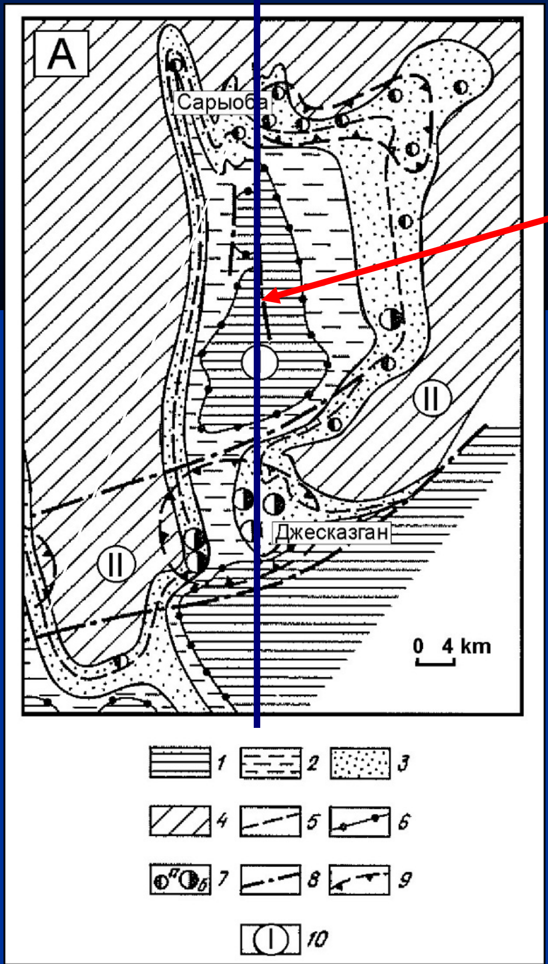
(Ji Kejian et al., 1992, 195 p)

Distribution of Cu



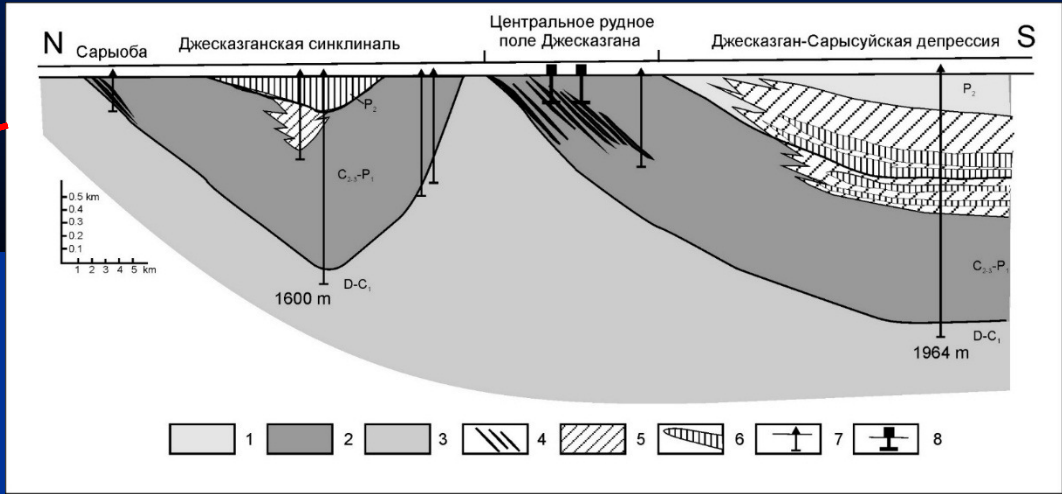
SEDIMENT-HOSTED STRATIFORM COPER DEPOSITS DZHESKAZGAN ORE REGION. KAZAKHSTAN

Geology



1 Carbonate rock (P2).
2. Red bed sandstone strata (P1)
3. Dzheskazgan suite (C2- 3 – P1)

Cross-section

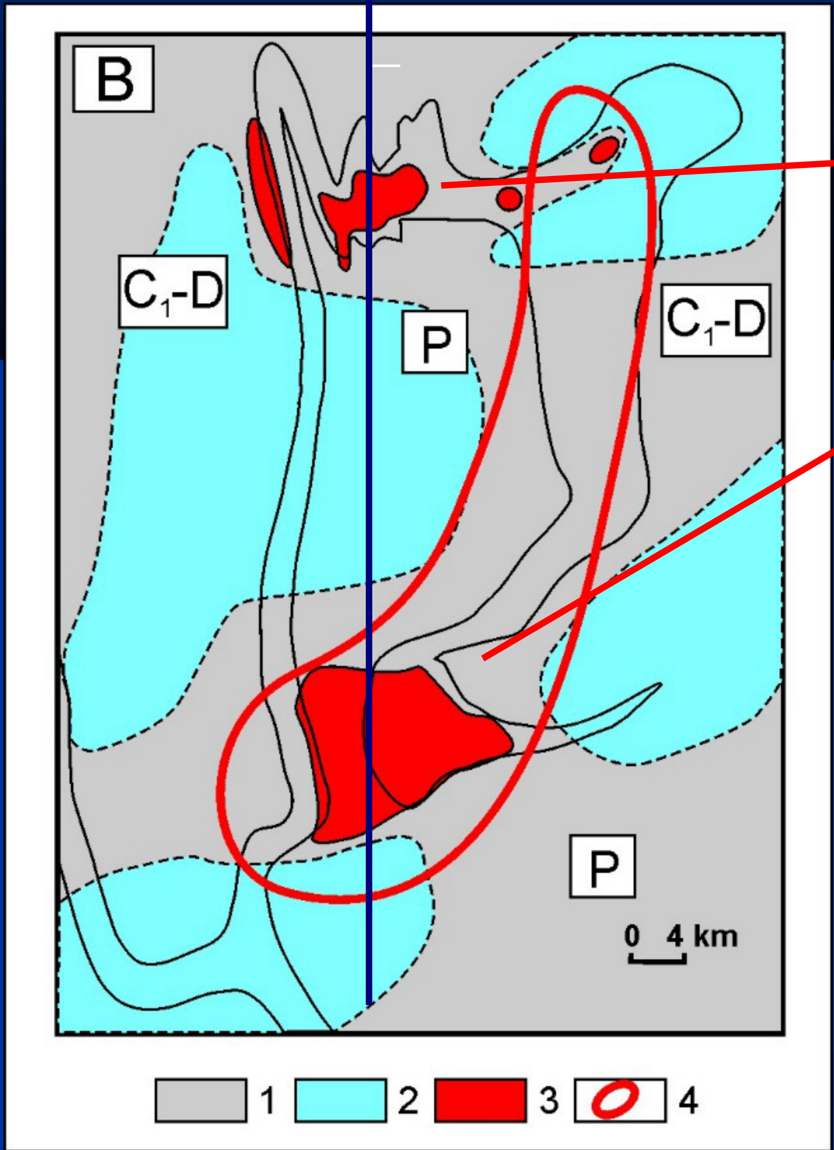


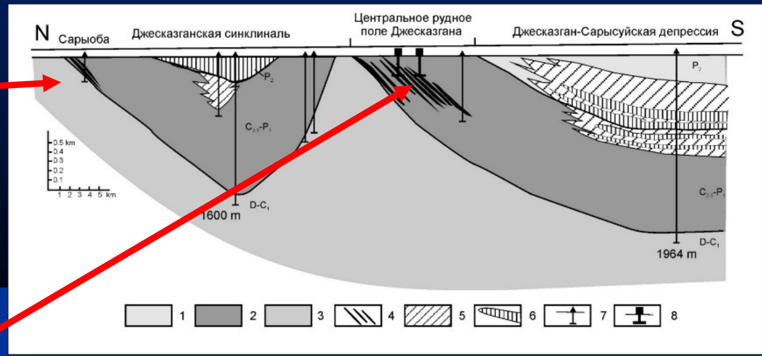
1 Terrigenious carbonate deposits (D- C1). 2. Dzheskazgan suite: red and grey bed sandstone , siltstone, conglomerate (C2-3 – P1) 3. Argilite (P2) 4.Ore body. 5 Enrichment zone of sulfate (1-0.5%). 6. Salt bearing deposits 7.Drill holes 8. Shaft

Modified after A,V. Kyslitzyn and V.O. Glebovsky (1983)

DISTRIBUTION OF Cu.

DZHESKAZGAN ORE REGION. KAZAKHSTAN



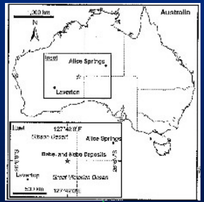


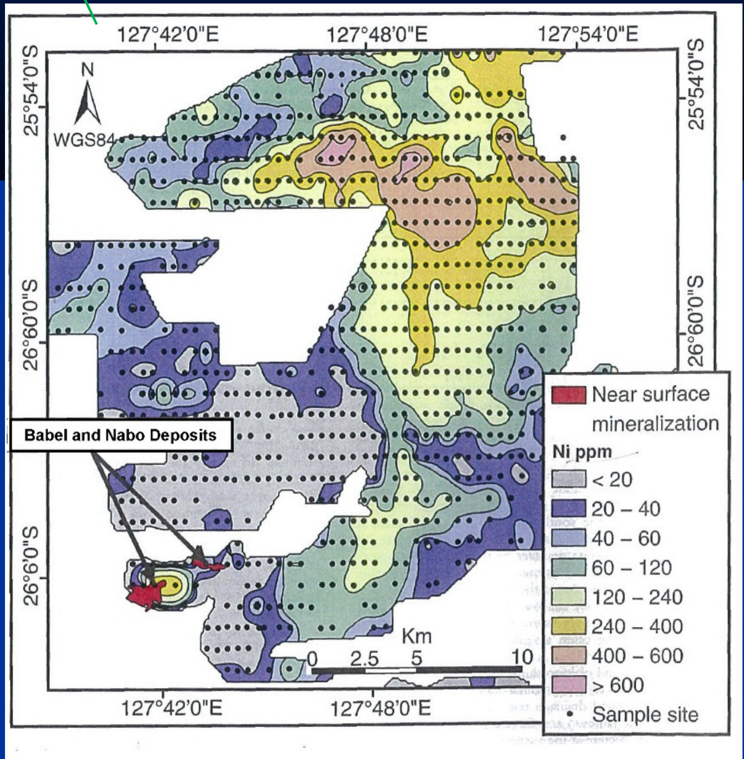
Simplified cross-section

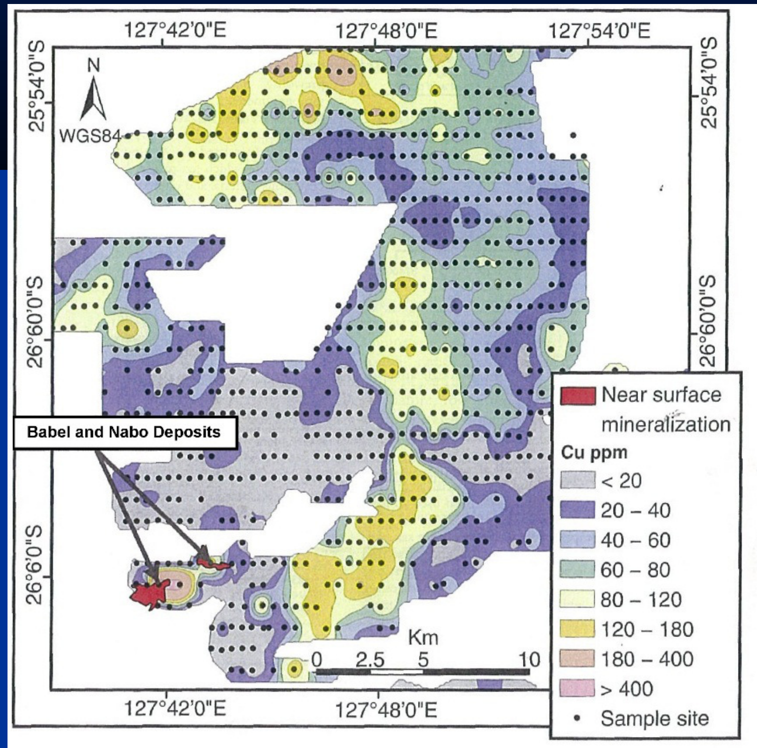
Reserves: 22 Mt Cu.
Background of Cu 30 -100 ppm
Enrichment zone of Cu, Pb, Zn – 45 sq,km. Cu > 100 ppm
Depletion zone – 20 -25 ppm
Area- 1000 sq. km.

Cu deficit - 25 Mt
(Estimated by 500 m of depth)

BABEL and NEBO Ni-Cu PGE deposit
Central Australia

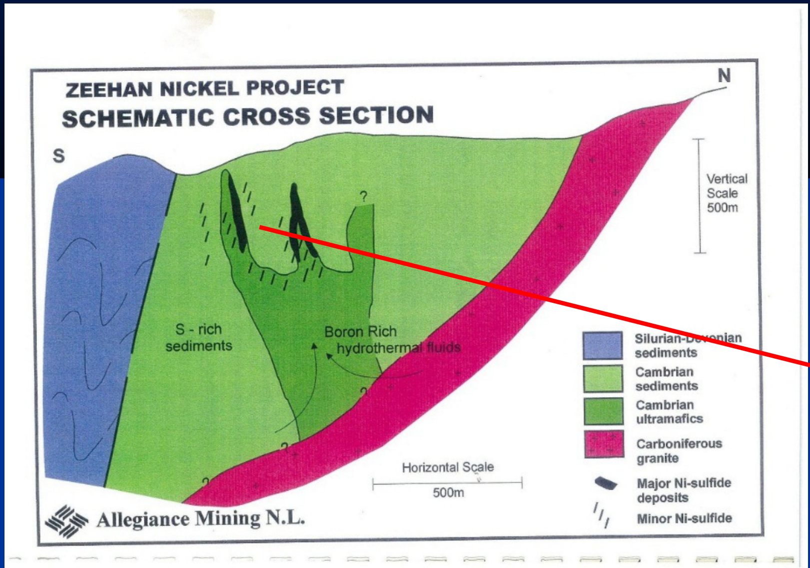


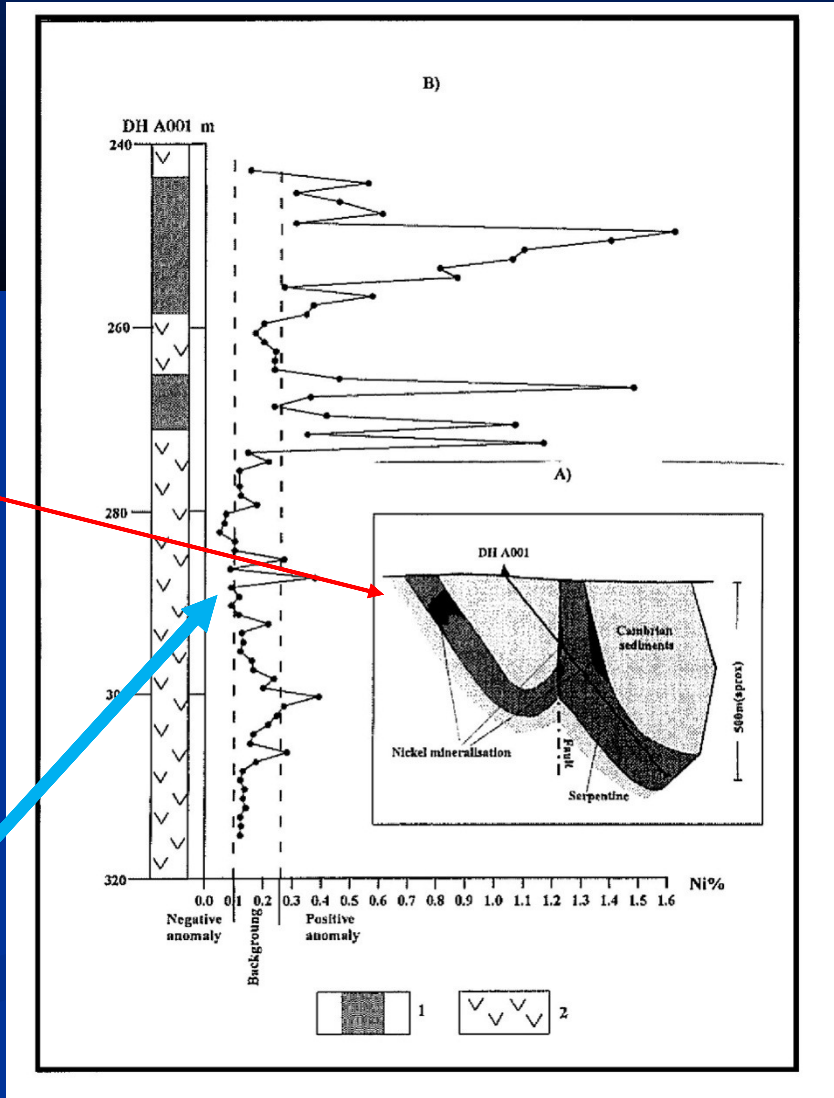




Ultramafic rock hosted in amphibolite (Middle Proterozoic).
Area of geochemical mapping - 1700 sq km.(Grid 1 км X 0.5 км. Total – 1700 samples)
Thickness of cover - 10 м. Area of Ni and Cu less then 20 ppm – 100 sq. км

Ni DEPOSIT AVBURY
IN ULTRAMAFIC ROCK
WSTERN TASMANIA

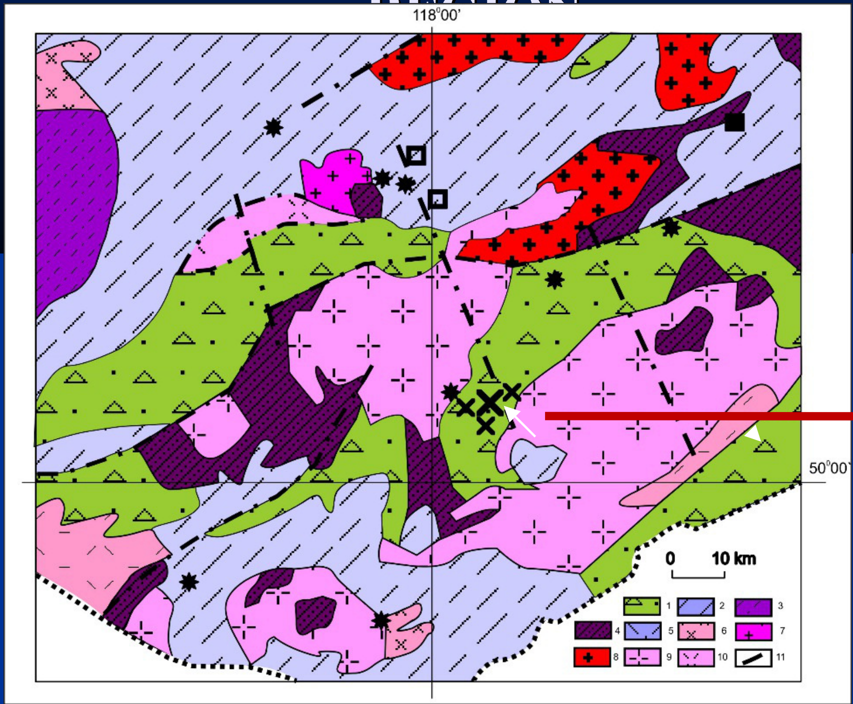




S-D Sediments
Cm Sediments
Cm Serpentinizied Ultramafic intrusion
Cr granites
Ni in ore bodies – 1.5 -1.8%
Ni in dunite (background) – 1500 – 2500 ppm
Depletion zone (in dunite) Ni - 200 – 500 ppm

Mo-U ORE DEPOSITS. ZABAYKALIE. RUSSIA

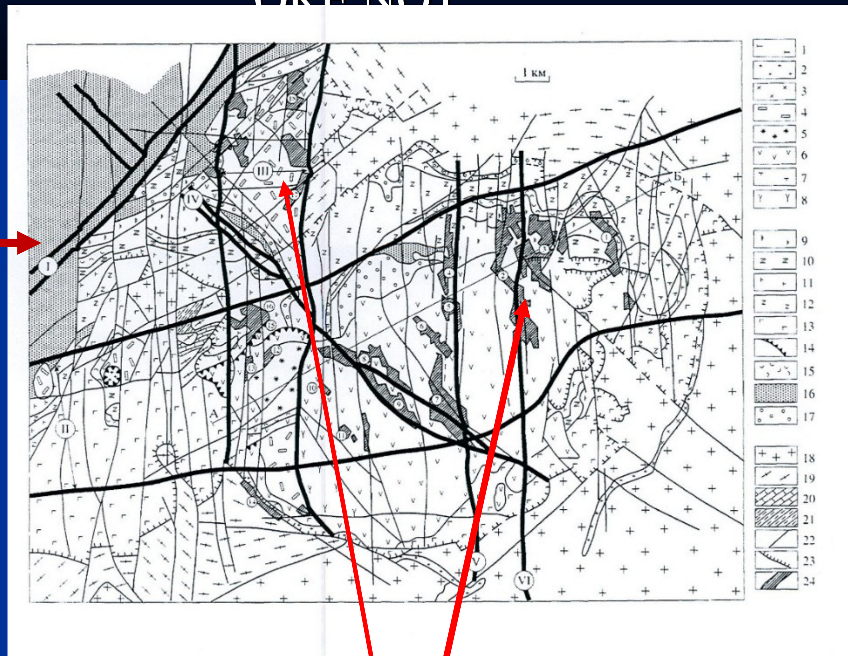
GEOLOGY OF STRELTZOVSKY ORE REGION



1. Terrestrial deposits(K1) 2.J deposits. 3. P deposits 4. Metamorphic rock. 5. Rhyolite, andesite, felsitic lavas (J2). 6. Grante (J 3) 7. Granite (J3) 8. Granite (J3). 9. Granite (Pr2) 10. Granie (Ar)

GEOLOGY OF STRELTZOBSKY

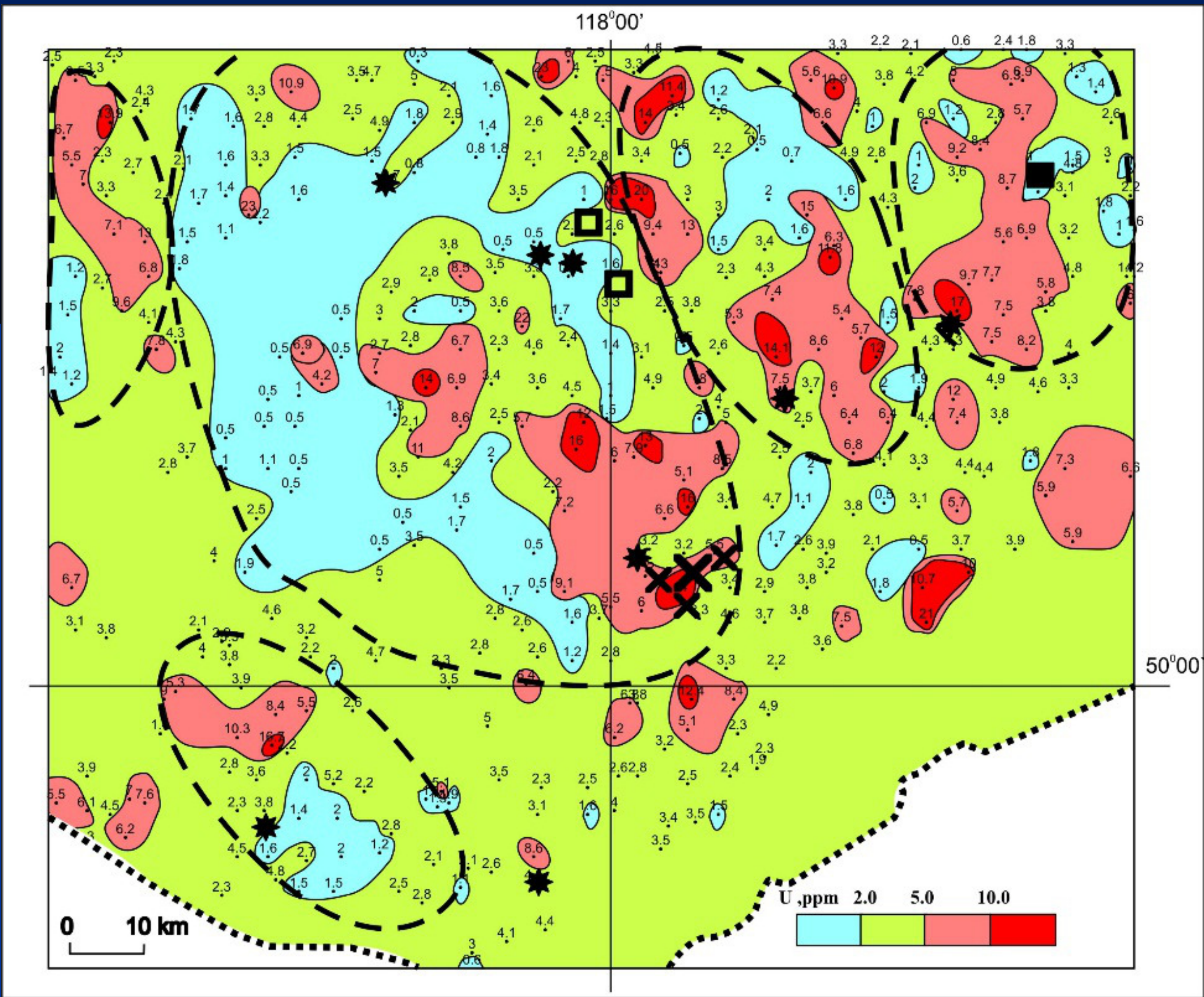
ORE NOT



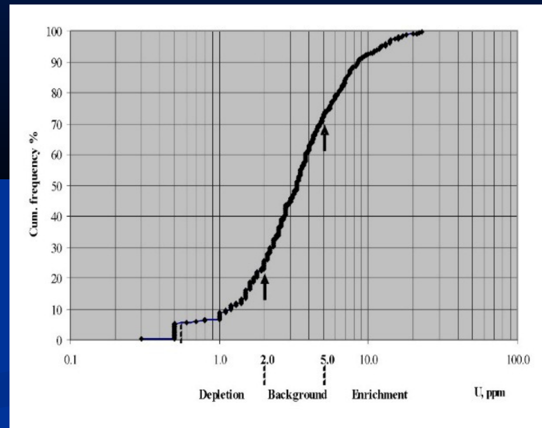
Uranium ore deposits are localized into basalt-rhyolite caldera

STRELTZOVSKY ORE REGION. ZABAYKALIE

DISTRIBUTION OF U



Cumulative distribution plot of U



Enrichment zone > 8.9ppm

Depletion zone < 1.28 ppm

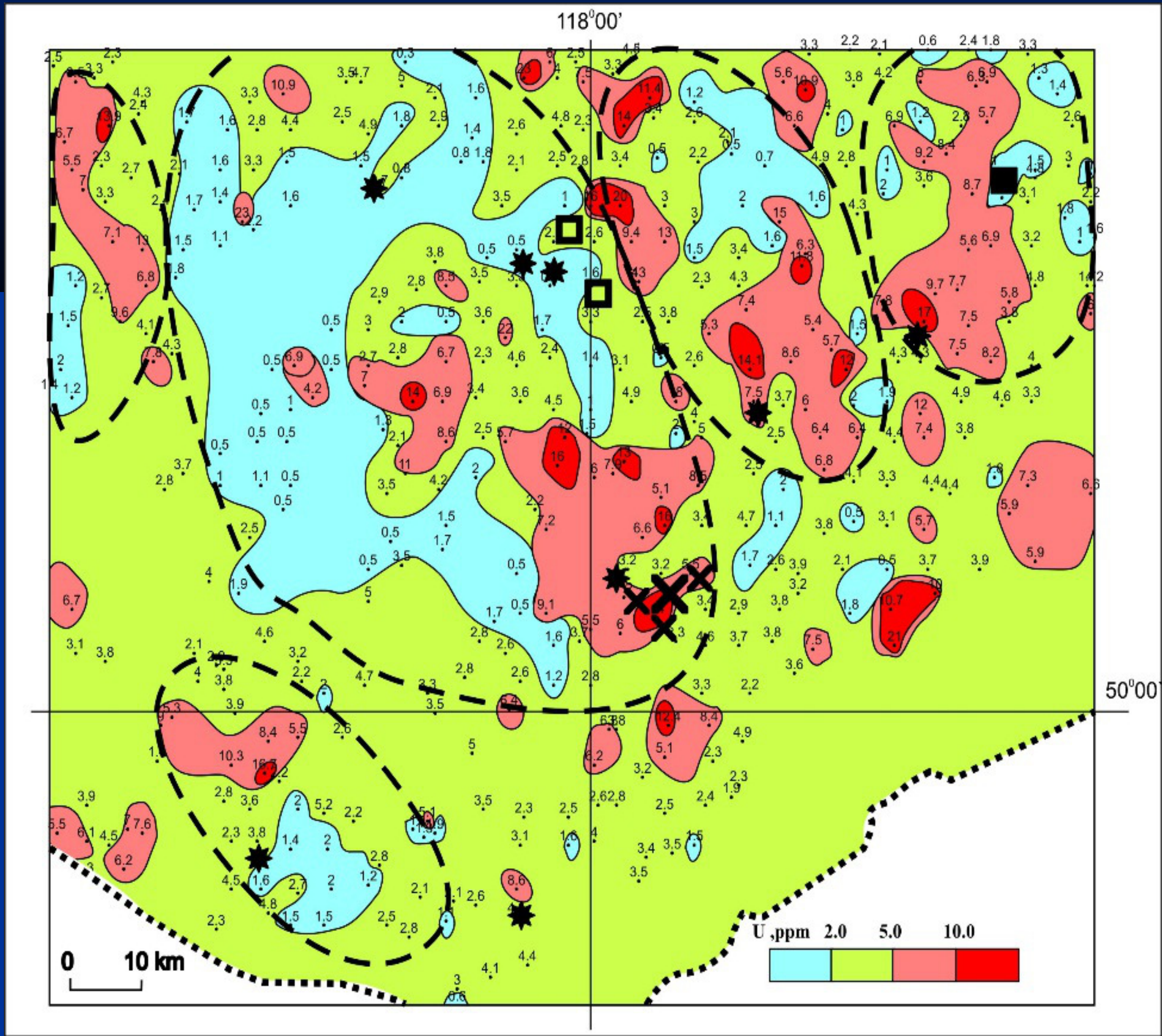
Background - 3.28ppm

S – 15 000 sq. km. Rock samples -550. 1s/25-30

STRELTZOVSKY ORE REGION. ZABAYKALIE
DISTRIBUTION OF U

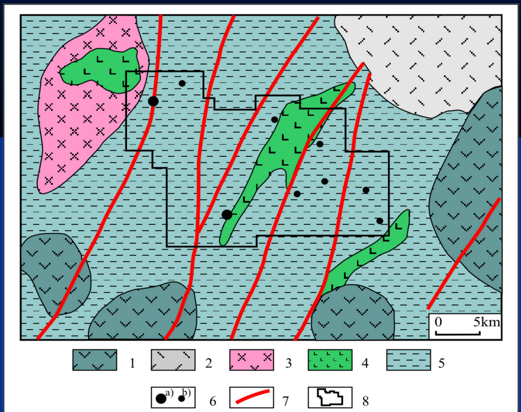
Reserves U- 250 000 t
Enrichment zone - **650 sq km**.
Depletion zone - **2020 sq km**.

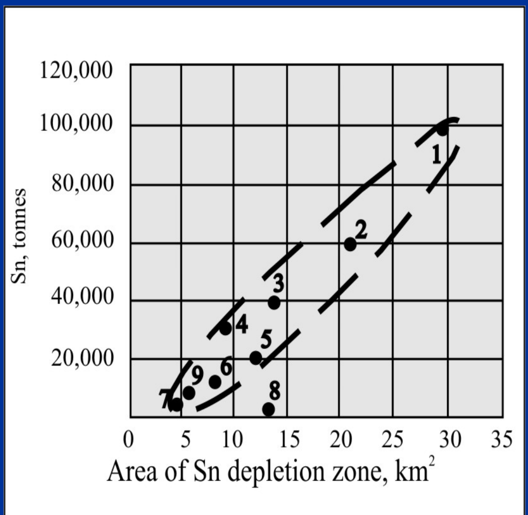
Enriched U – 3.2 Mt
Deficit U -5 Mt
(Estimated by 500 m of depth)



Sn DEPOSITS. KAVALEROBSKY ORE REGION. FAR EAST .RUSSIA

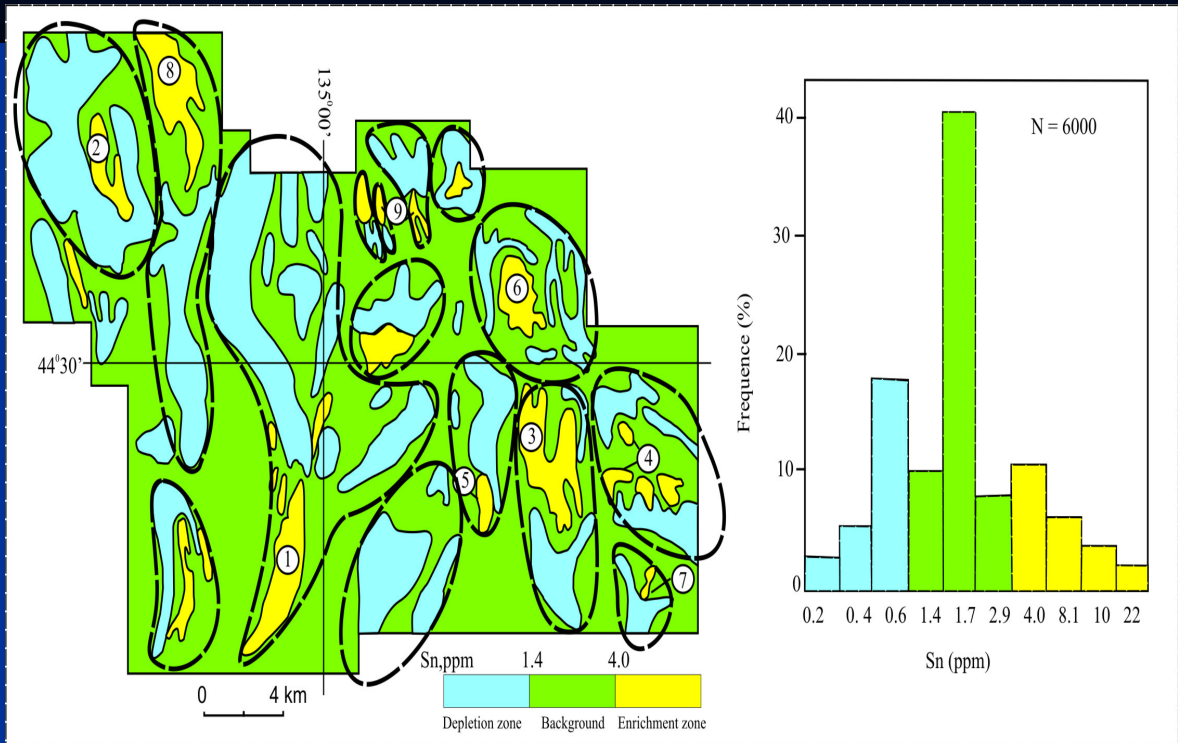
GEOLOGY





DISTRIBUTION OF Sn

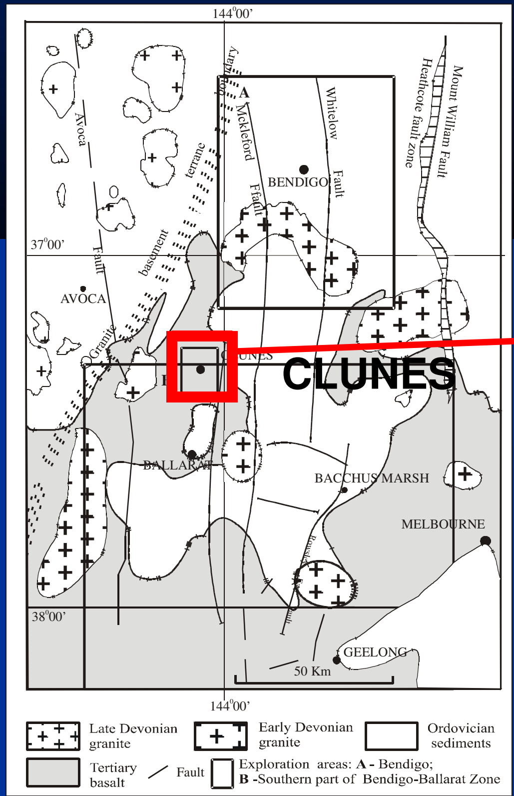
Area – 500 sq km, 6000 rock samples (Mz turbidity)

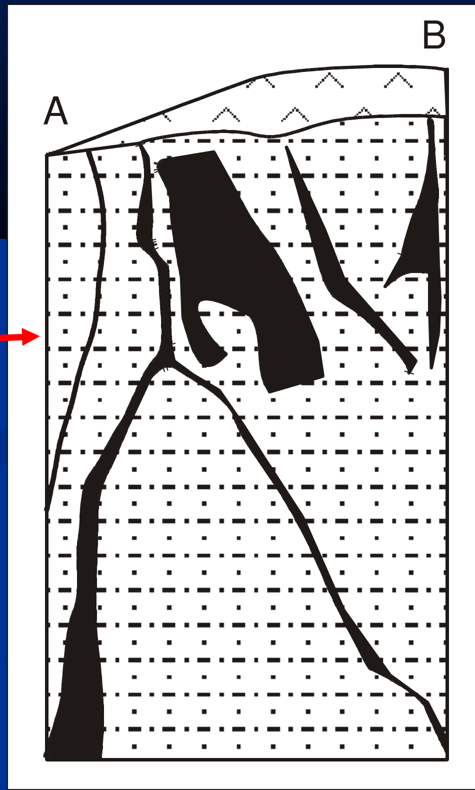


1-9 Sn deposits

Clunes turbidity hosted gold deposit under basalt

- The ore bodies of saddle-shaped form are located in the Ordovician sequences and are overlapped by basalts of 20 -60 meters.
- In this area for mapping we used a selective extracting method (TMGM)



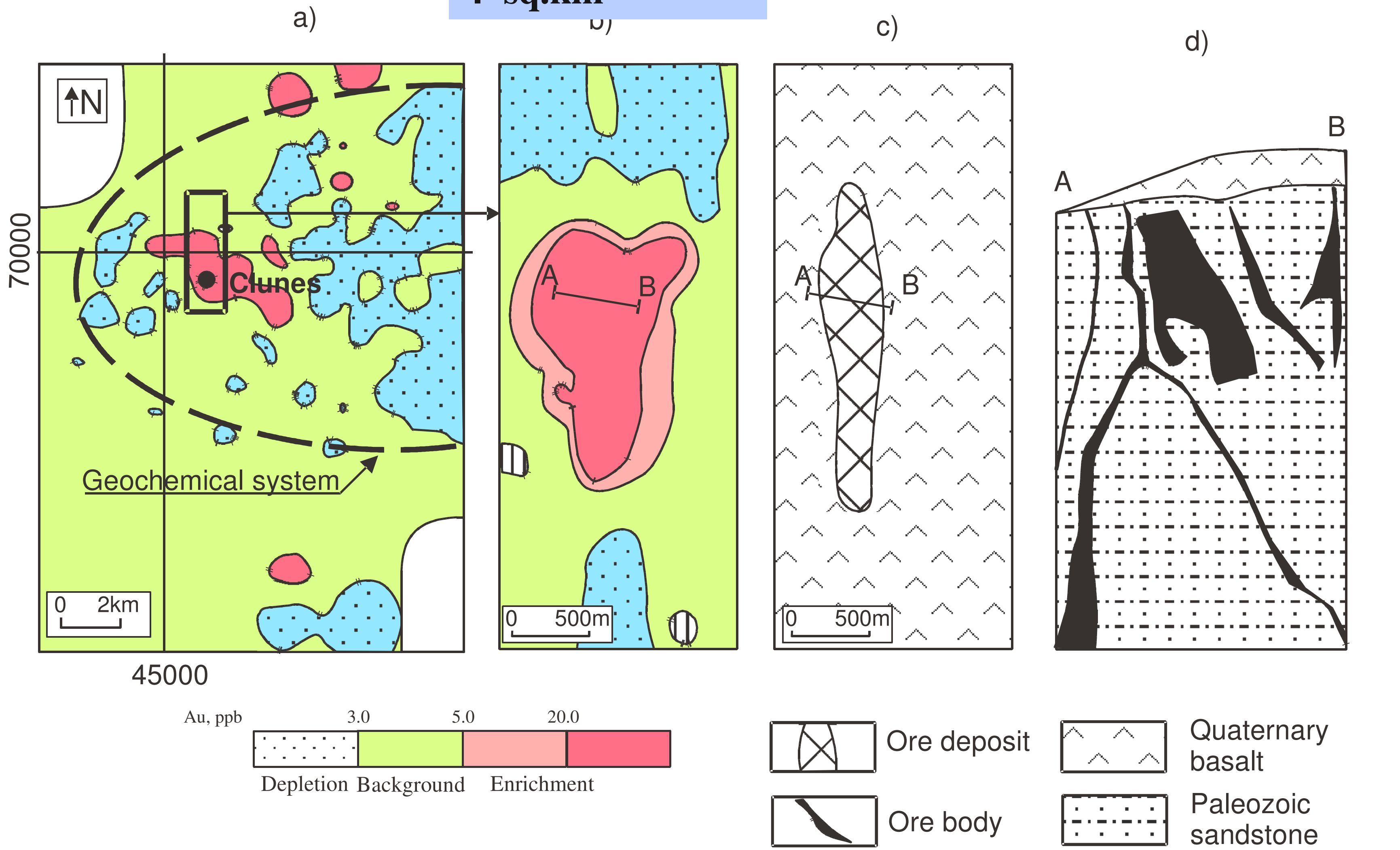


Bendigo-Ballarat gold province, Australia

Clunes turbidity hosted gold deposit under basaltsr

1s/1 sq km
200 sq.km

100s/1 sq km
4 sq.km



Discussion and Conclusion

1. Polar geochemical ore systems have been established at different scales from regional to local and different types of mineralization.

2. The geochemical pattern of these systems indicates a universal mechanism of formation.

This includes the spherical or ellipsoidal form of the systems. It can be assume the frontal migration of ore elements from the boundaries of systems to the centres of ore precipitation.

3. Such structure wc explain on base of geoelectrochemical model.

GEOELECTROCEMICAL SYSTEMS IN EARTH'S CRUST

In Earth's crust to exist different types of sources electrical energy (E). For example: fluid movements lead to electrical potential. There are other sources (self-potential – SP) of electrical energy, including SP, when stressed blocks of rock in active geo-dynamic environments and etcetera.

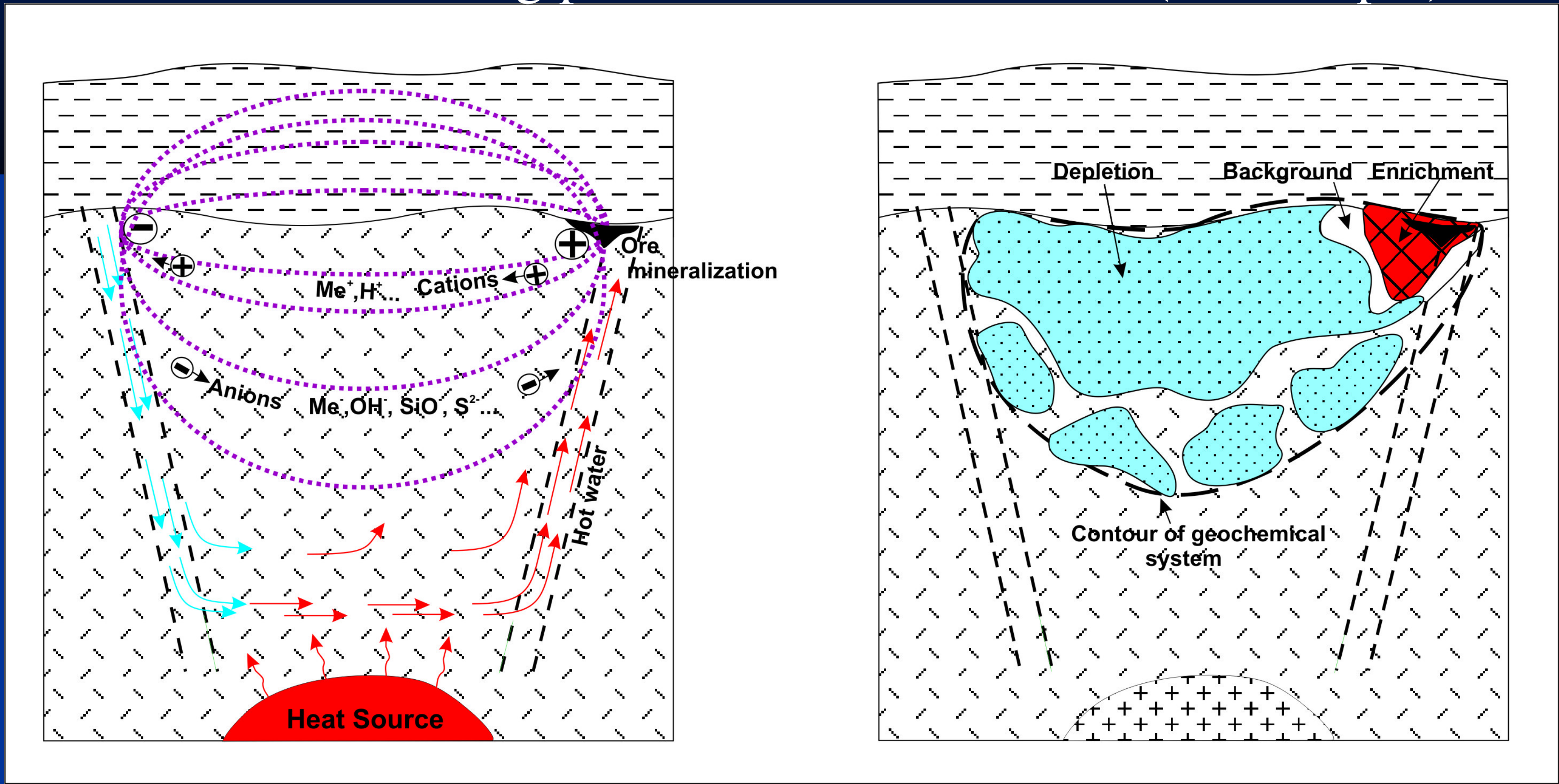
.

Electrical energy in Earth's crust inevitable provokes a redistribution of chemical elements in electrical fields, forming geochemical systems of polar structure. Studies of the electrochemical kinetics of the extraction and redistribution of elements conducted in the development of the CHIM geo-electrochemical method

The inclusion of an electrochemical mechanism in ore formation processes gives us greater freedom in discussing aspects of the genesis of ore deposits, include formation polar geochemical systems .

GEOELECTROCHEMICAL MODEL OF ORE FORMATION

Convection cell sub-seafloor hydrothermal systems and Steaming potential electrical field (as example)



On base of empirical and theoretical data of redistribution ore-forming and associated elements within a particular geological space with forming polar geochemical systems was created

IONEX TECHNOLOGY

IONEX TECHNOLOGY

IONEX Technology is usually employed in sequence of stages from a regional survey to progressively more- detailed follow-up.

The basic model of IONEX's Technology is carry out in four stages with density of sampling:

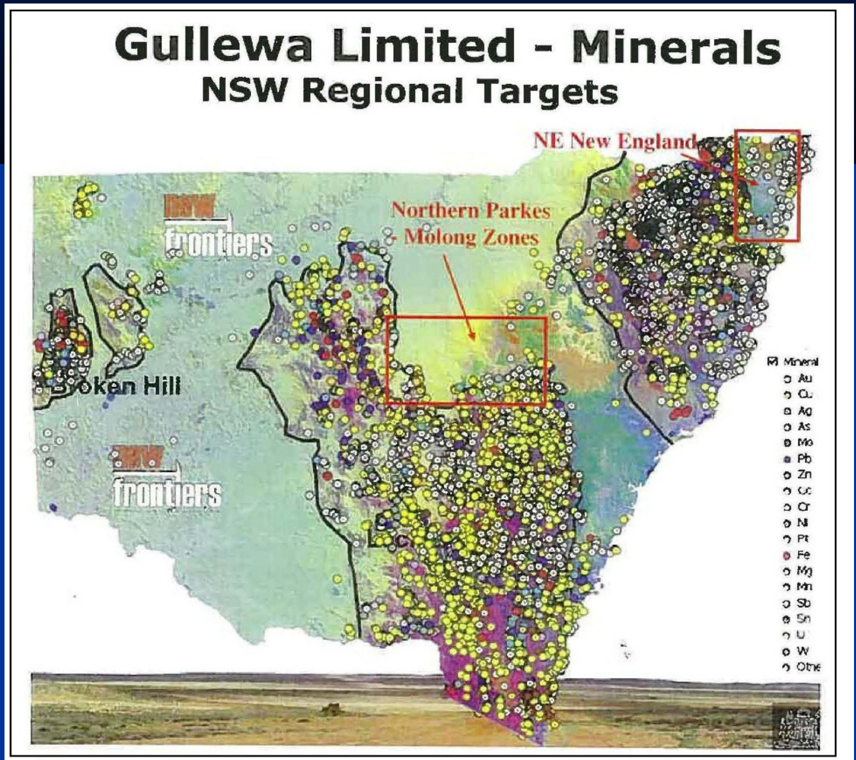
- Stage I -1 sample/25 sq.km (area ~n.1000 sq km)
- Stage II – 1 sample/1 sq.km (area ~n.100 sq km)
- Stage III - 16 samples/1 sq.km (n.10 sq km)
- Stage IV - 100 samples/ 1 sq.km (n,1 sq km)

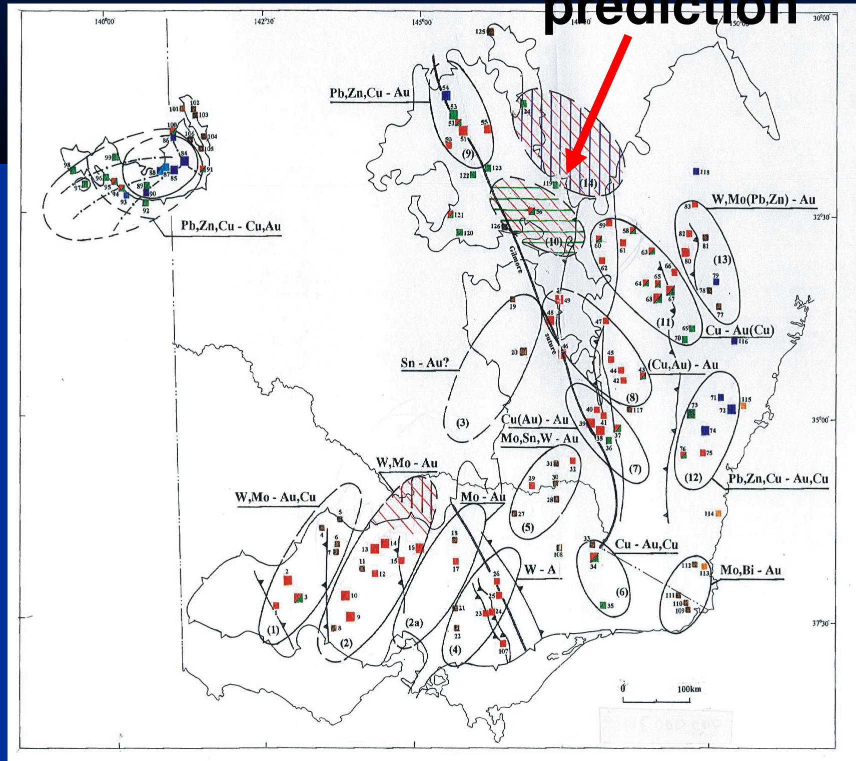
Available geological and geophysical data is incorporated in the interpretation of the geochemical results.

GOLD EXPLORATION ON COVER AREA IN NSW AUSTRALIA BY IONEX TECHNOLOGY

RECOGNISION STAGE

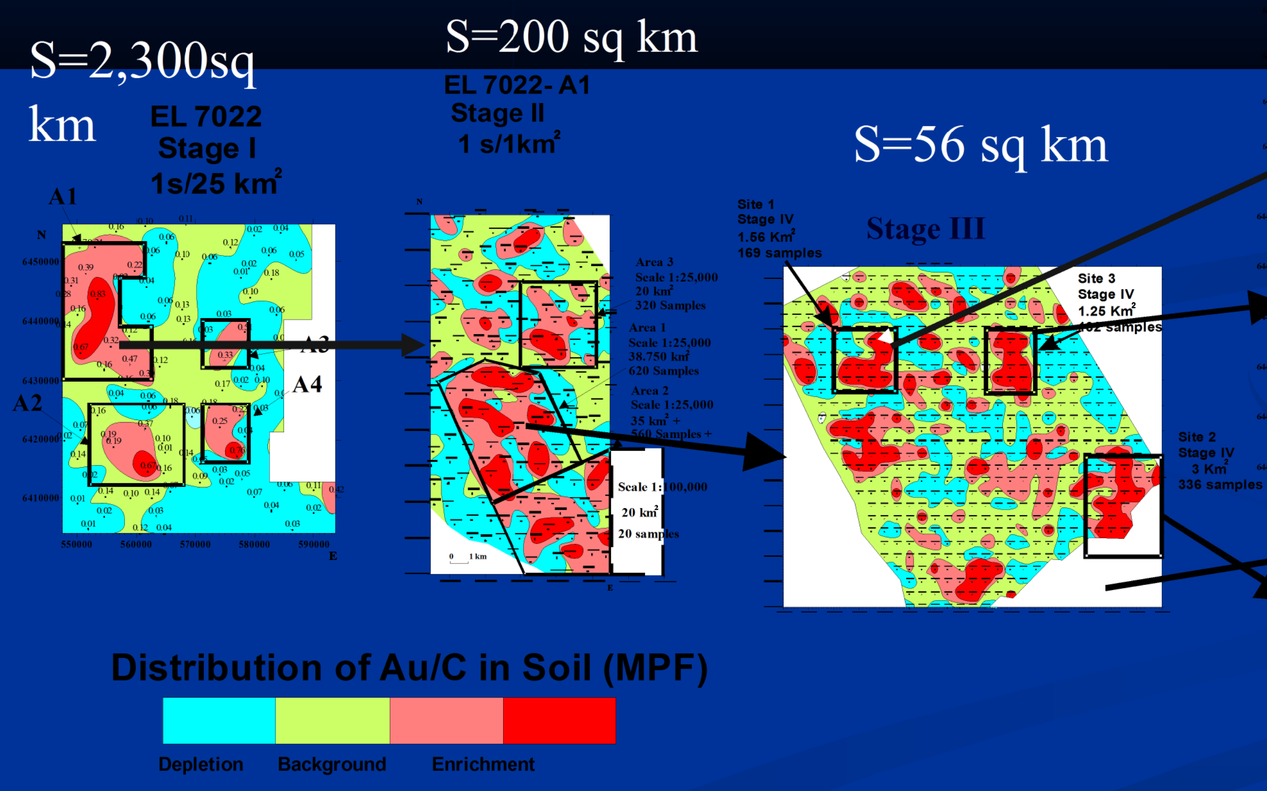
Au-Cu mineralization prediction

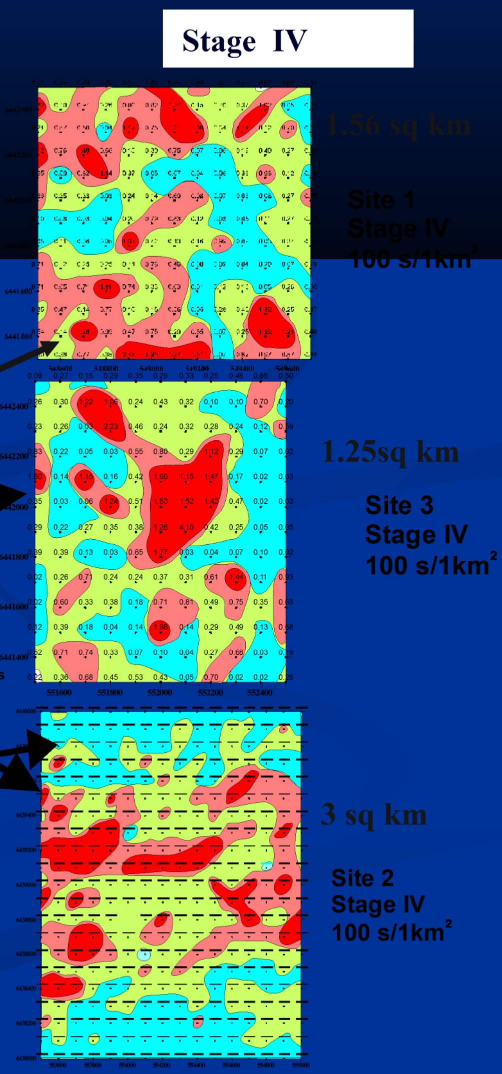




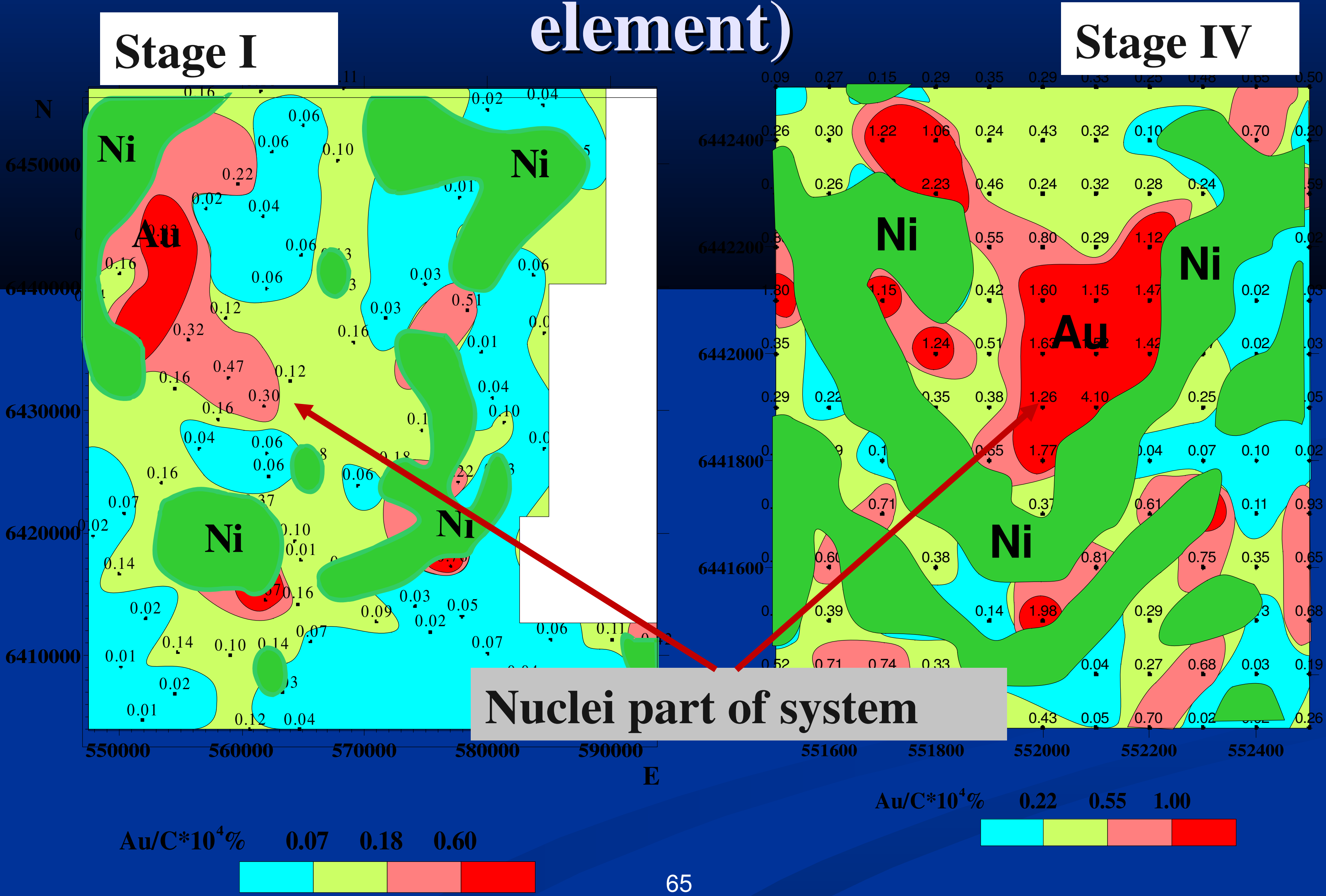
GOLD EXPLORATION ON COVER AREA IN NSW BY IONEX TECHNOLOGY

In the Dandaloo area four stages of geochemical exploration were carried out in scales of 1:500,000 to 1:10,000 by MPF selective extraction method





Distribution of Au and Ni (siderophile element)



THE EHD