THE IMPACT OF HYDROTHERMAL SYSTEMS ON THE WORLD ECONOMY

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Some aspects of Hydrothermal Mineralisation

History

Hydrothermal Metals exploited

Processes

Deposit types

History

Agricola 1556: veins post-dated host, circulating meteoric water

Descartes 1644: deeper origins water and metals

Price 1788: salts, acids and fissures

History

Hutton and Werner late 18th C disagreed - molten or sedimentary

Hutton linked magmas and ores

Werner recognised marine sedimentary processes

History

De Beaumont 1847: transport by reversible chemical reactions zones of regional crustal weakness

Hunt 1861: solutions from metamorphism with organic matter an agent of deposition

Processes of Formation

Ingredients:

Water, alkalis, halides, metals - complex ions,

Temperature usually at least warm

Conduits to and from solution site

Suitable host depositional environment

Definitions (AGI Glossary of Geology)

Hydrothermal: of or pertaining to hot water with or without igneous association between 50° and 700° C

Hydrothermal Alteration: alteration of rocks by hydrothermal processes

Metasomatism: chemical alteration of a solid rock by liquids or gases –

Diffusion

Commodities exploited

Virtually all – one exception Cr

Periodic table

Nonmetals	Other Nonmetals	Carbon Phosphorus Sulphur Oxygen Nitrogen
	Halogens	Fluorine Chlorine bromine
	Noble Gases	Helium Neon Argon
Metalloids	Metalloids	Boron Silicon Antimony Arsenic
Metals	Alkali metals	Lithium Sodium Potassium
	Alkaline earth metals	Beryllium Magnesium Calcium
	Lanthanoids	Lanthanum Cesium Samarium
	Actinoids	Actinium Thorium Uranium
	Transition metals	Copper Iron Gold Platinum
	Post-transition metals	Ununtrium Flerovium Ununpentium Livermorium

Periodic table - 240 elements

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 - 72	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 - 103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
Lanthanoides				58 La	59 Ce	60 Pr	61 Nd	62 Pm	63 Sm	64 Eu	65 Gd	66 Tb	67 Dy	68 Ho	69 Er	70 Tm	71 Yb	72 Lu
Actinoides				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Periodic table - 164 hydrothermal elements

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1																		
2	3 Li	4 Be											5 B				1 F	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	
4	19 K	20 Ca	21 Sc	22 Ti	23 V		25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	
6	55 Cs	56 Ba	57 - 72	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi			
7	87 Fr	88 Ra	89 - 103															
Lanthanoides				58 La	59 Ce	60 Pr	61 Nd	62 Pm	63 Sm	64 Eu	65 Gd	66 Tb	67 Dy	68 Ho	69 Er	70 Tm	71 Yb	72 Lu
Actinoides					90 Th		92 U		94 Pu				98 Cf					

Deposit styles –

water as a concentrating agent

- Veins
- Metasomatic
- Pegmatites
- Stratabound
- Supergene
- Brines
- Porphyries
- IOCGU
- Carbonatites
- Volcanic
- Weathering
- Other

Deposit styles

Veins - 18 elements

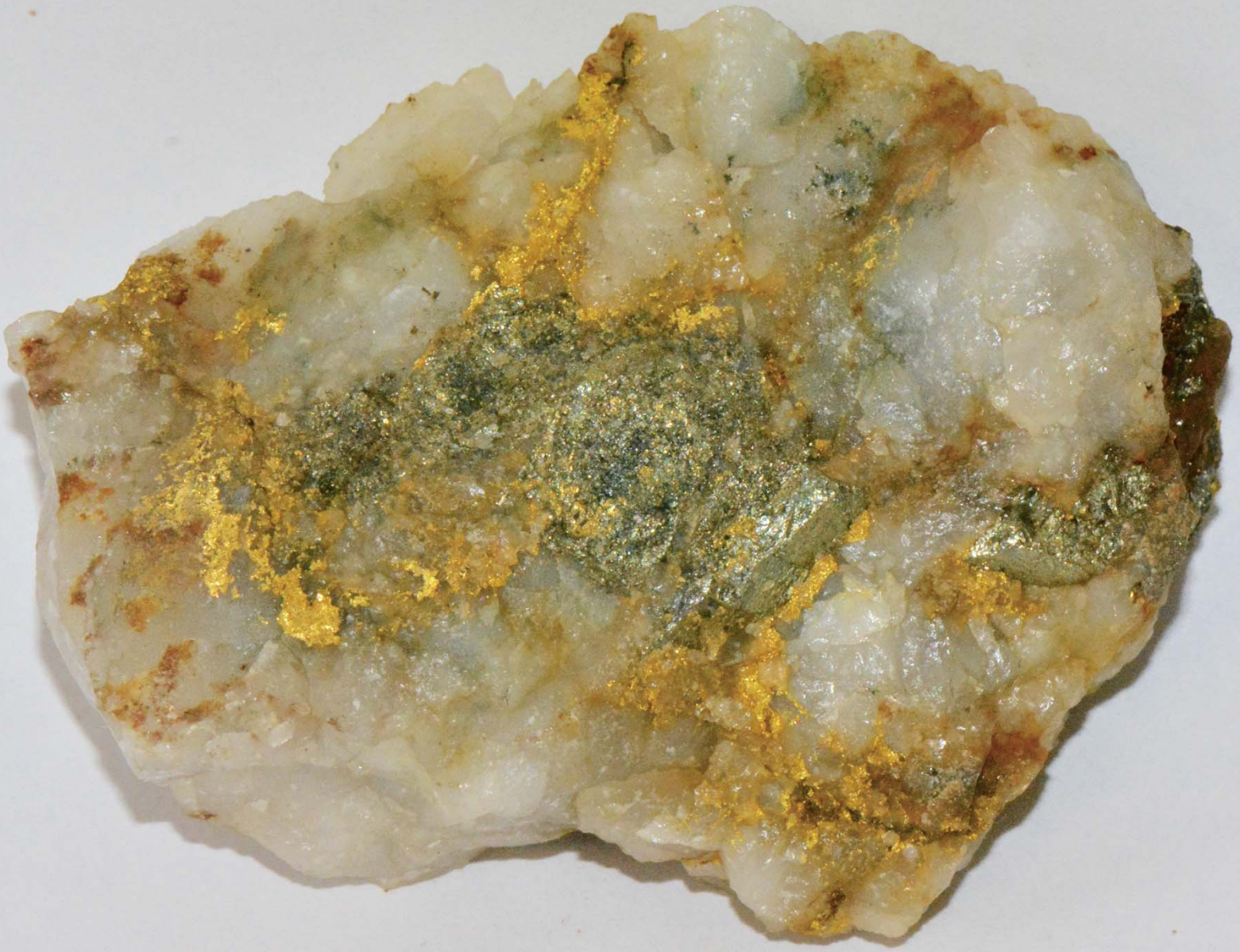
Au Cu Co Si Ni Zn As

Mo Ag Cd Sn Sb Te Ba

W Pb Bi Hg

Deposit styles

Veins, stockworks



Deposit styles

Porphyries

Cu Mo Au

Porphyries

Large intrusion-related hydrothermal systems containing Cu, Mo, Au

Intermediate to felsic, porphyritic 0.5 to 8 km across intruded at depths 1 to 2 km

Larger bodies tend to be complex with multiple intrusions

Subduction plate margin setting

Average Cu rich deposit 450Mt at 0.64%

Porphyries

Wall rocks from Precambrian gneiss to Phanerozoic sediments control alteration style

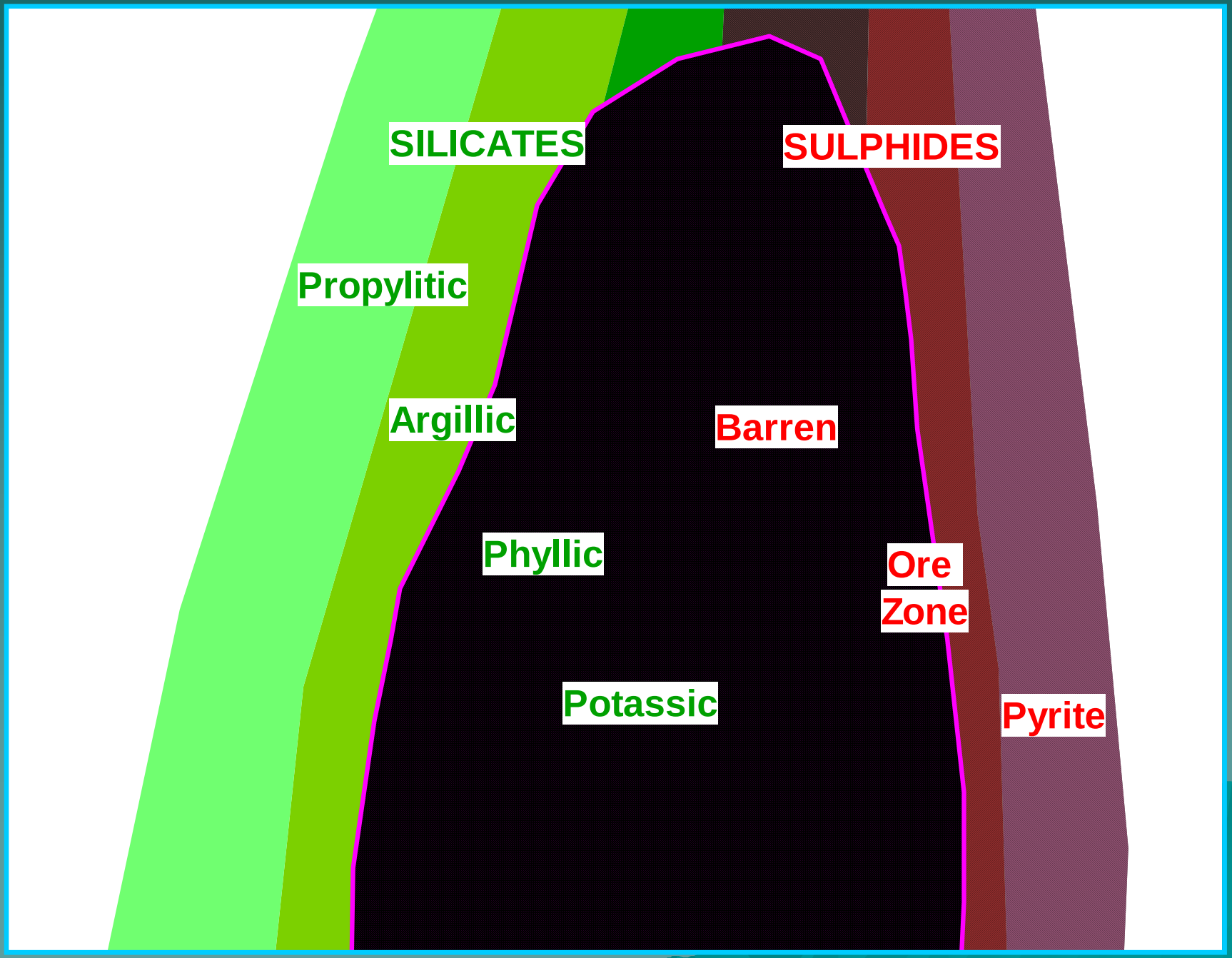
Generally similar alteration except for carbonate wall rocks (skarns)

Concentrically Zoned:

From disseminations to veins, barren through ore to pyritic

From potassic to propylitic silicate alteration

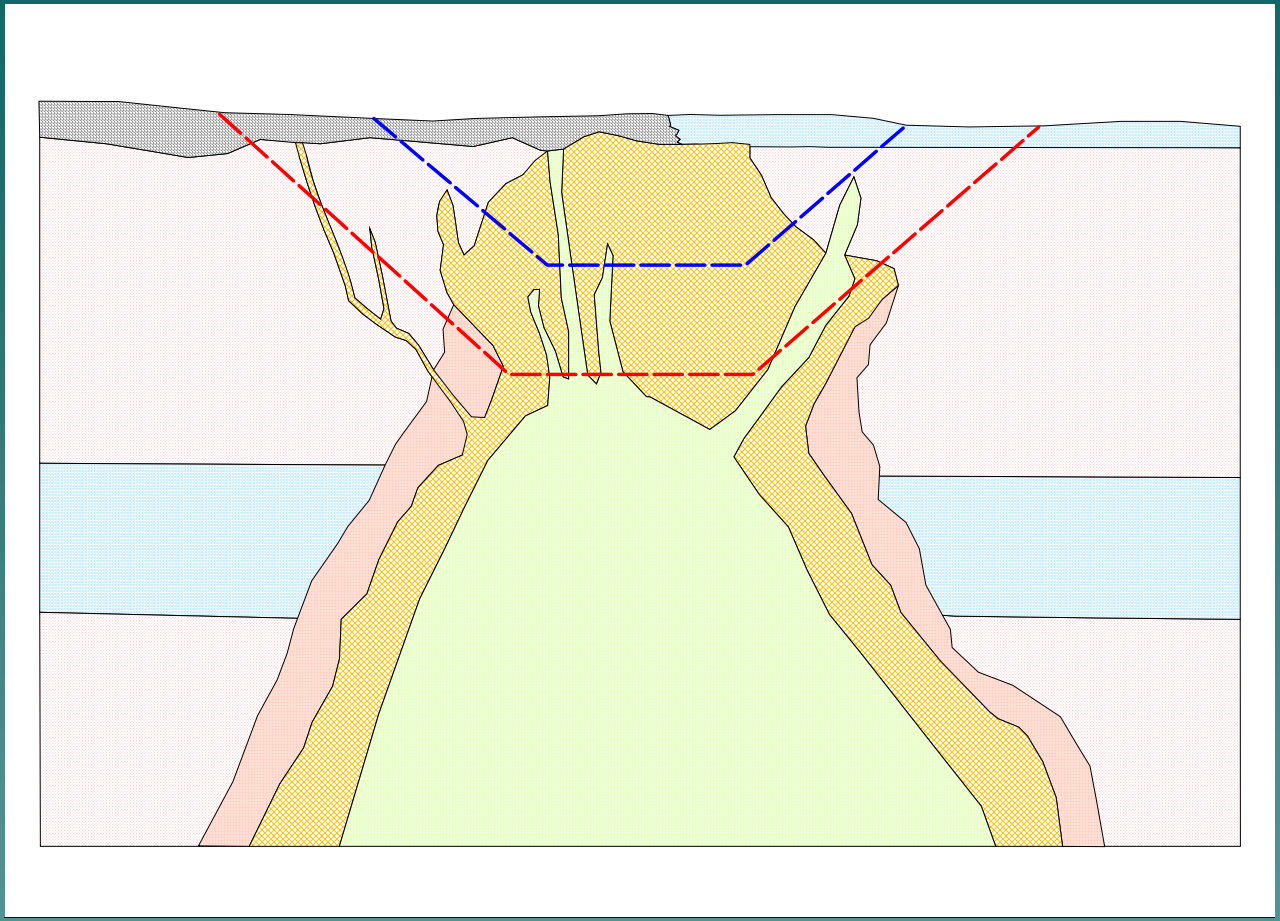
Porphyries

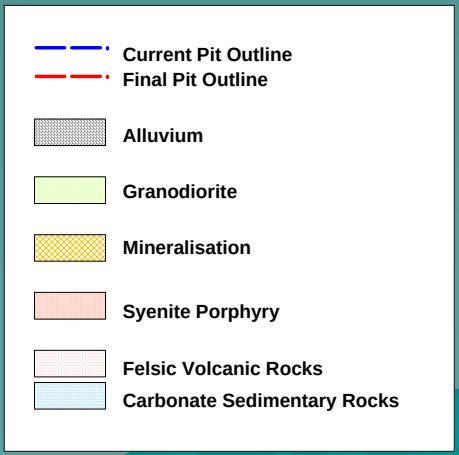

SILICATES
SULPHIDES
Propylitic
Argillic
Barren
Phyllic
Ore
Zone
Potassic
Pyrite

Porphyries

Almalyk

Uzbekistan





Porphyries – Uzbekistan

Porphyries

Porphyries

Porphyries

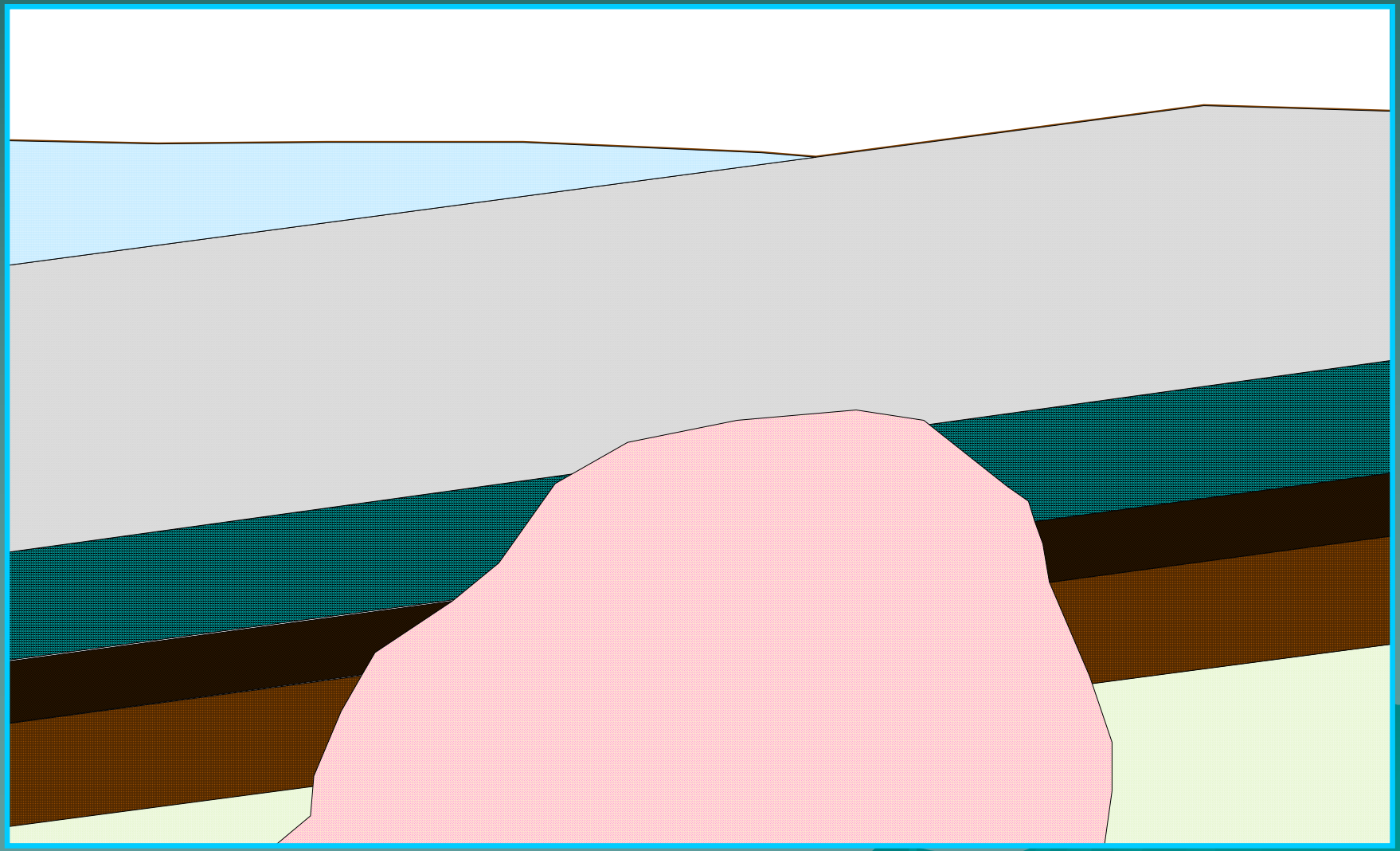
Deposit styles

Metasomatic deposits

Au Cu Mo W

Metasomatic deposits

Skarns Cu, W, Au and others



Skarns Kyrgyzstan

Deposit styles

IOCGU (Iron Oxide Copper Gold Uranium)

Fe Cu Au U

Deposit styles

Pegmatites

Be Li Cs Ta Nb P Sn (PGE)

Rare Earths

Gemstones

Quartz

Feldspar

Deposit styles and modern systems

Pegmatites Definition

Abnormally coarse-grained igneous rocks with a minor mention of water

Pegmatites and Pegmatoids

Pegmatoids can also destroy economic mineralisation (Bushveld IRUPS)

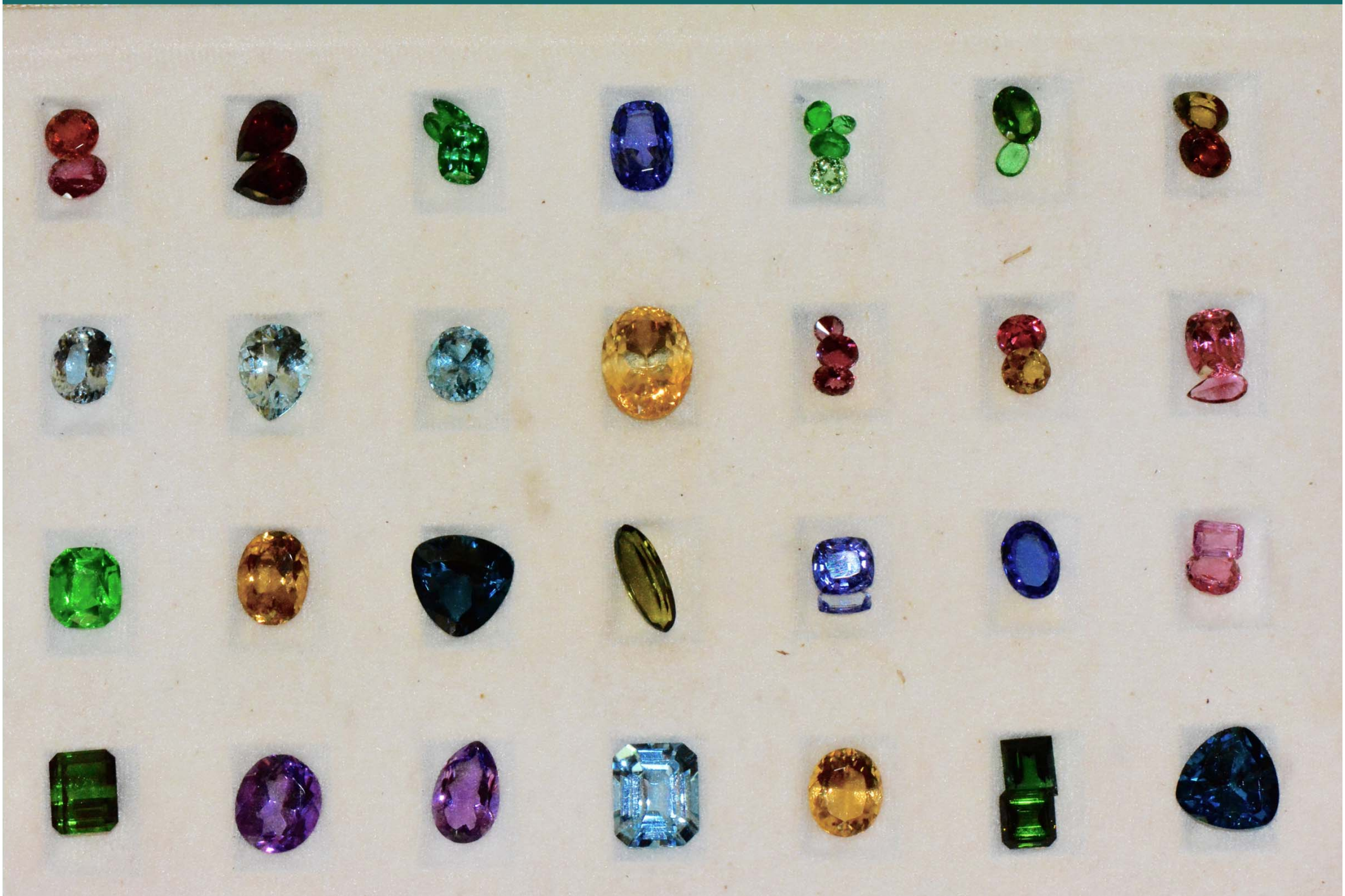
Deposit styles and modern systems

Pegmatites Be Li

Pegmatites

Pegmatites

Pegmatites



Deposit styles and modern systems

Carbonatites

Cu Nb P Fe Ti

Rare Earths

Vermiculite

Carbonatites

Carbonatites

Volcanic associations Mn

Volcanic associations

Deposit styles

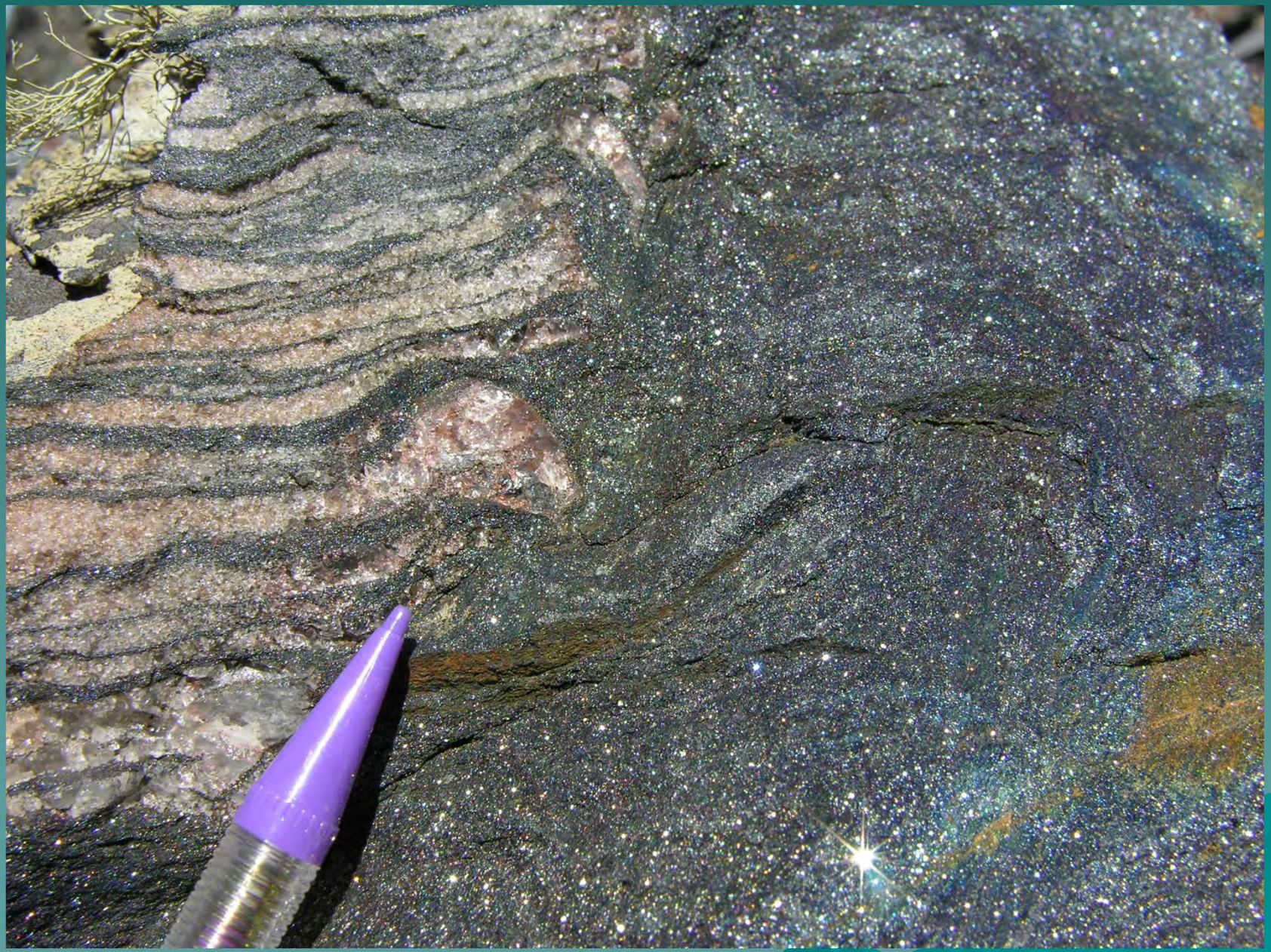
Subtraction hydrothermal

Can be hot or surface temperature

Fe Mn Ni Al

Supergene – subtraction/addition

Supergene – subtraction/addition



Supergene – subtraction/addition

Supergene – subtraction/addition

Supergene – subtraction/addition

Supergene – subtraction/addition

Other – subtraction hydrothermal Al

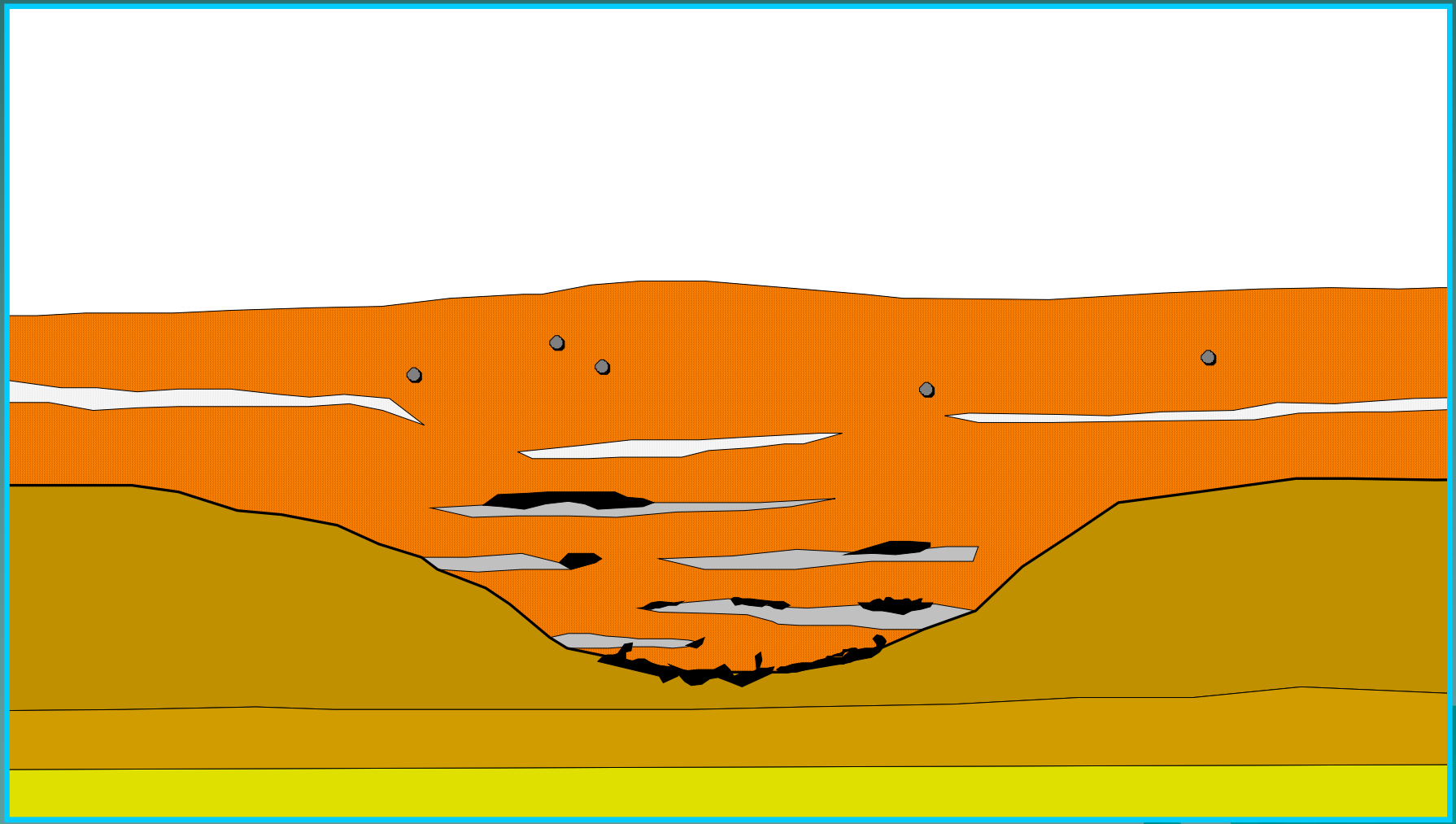
Deposit styles and modern systems

Stratabound

Sandstone hosted U, V

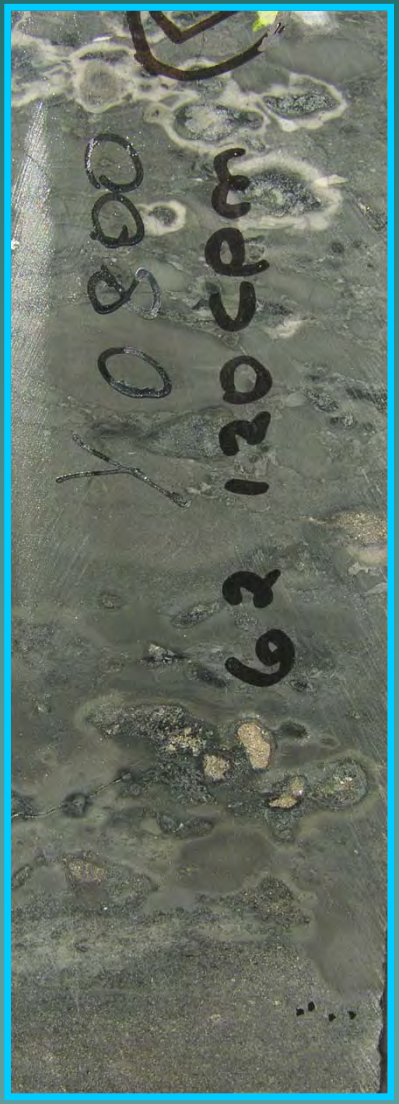
Stratabound

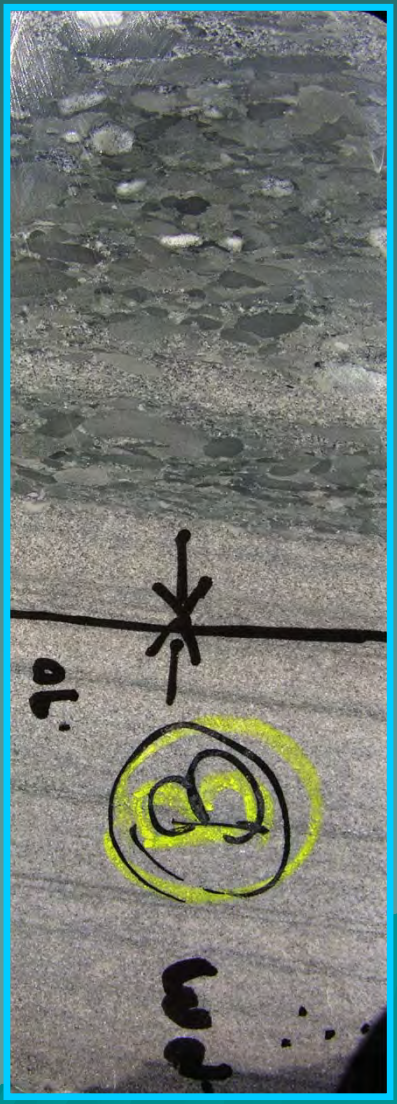
Sandstone hosted U, V



Stratabound

Sandstone hosted U, V





Stratabound

Sandstone hosted U, V

Deposit styles

Stratabound

Central African Copperbelt

Cu Co Ni

Mississippi Valley

Pb Zn Ag

Stratabound

Shale hosted Cu, Co (Central African Copperbelt)

Associated with carbon-rich shales and carbonates

Water and metal sources in rift / tensional sedimentary basins – red beds

Conduits created during compressional phase

Redox control on deposition

Stratabound

Shale hosted Cu, Co

Stratabound

Shale hosted Cu, Co

Stratabound

Carbonate hosted Pb, Zn (Mississippi Valley)

Open space porous limestone linked to regional faults accessing basement

Porous limestone – coral reefs, karst topography, collapse breccias

High salinity 15 to 25% - low temperature 100 to 150° C

Organic matter present (sometimes oil)

Stratabound

Carbonate hosted Pb, Zn (Mississippi Valley)

Metal, water and salts from sedimentary package

Migration through regional structures

Precipitation in open spaces triggered by organic matter

Stratabound Zeerust Fluorite

Dolomites of the Transvaal Supergroup

Mineralisation in open spaces: disseminated, veins blobs

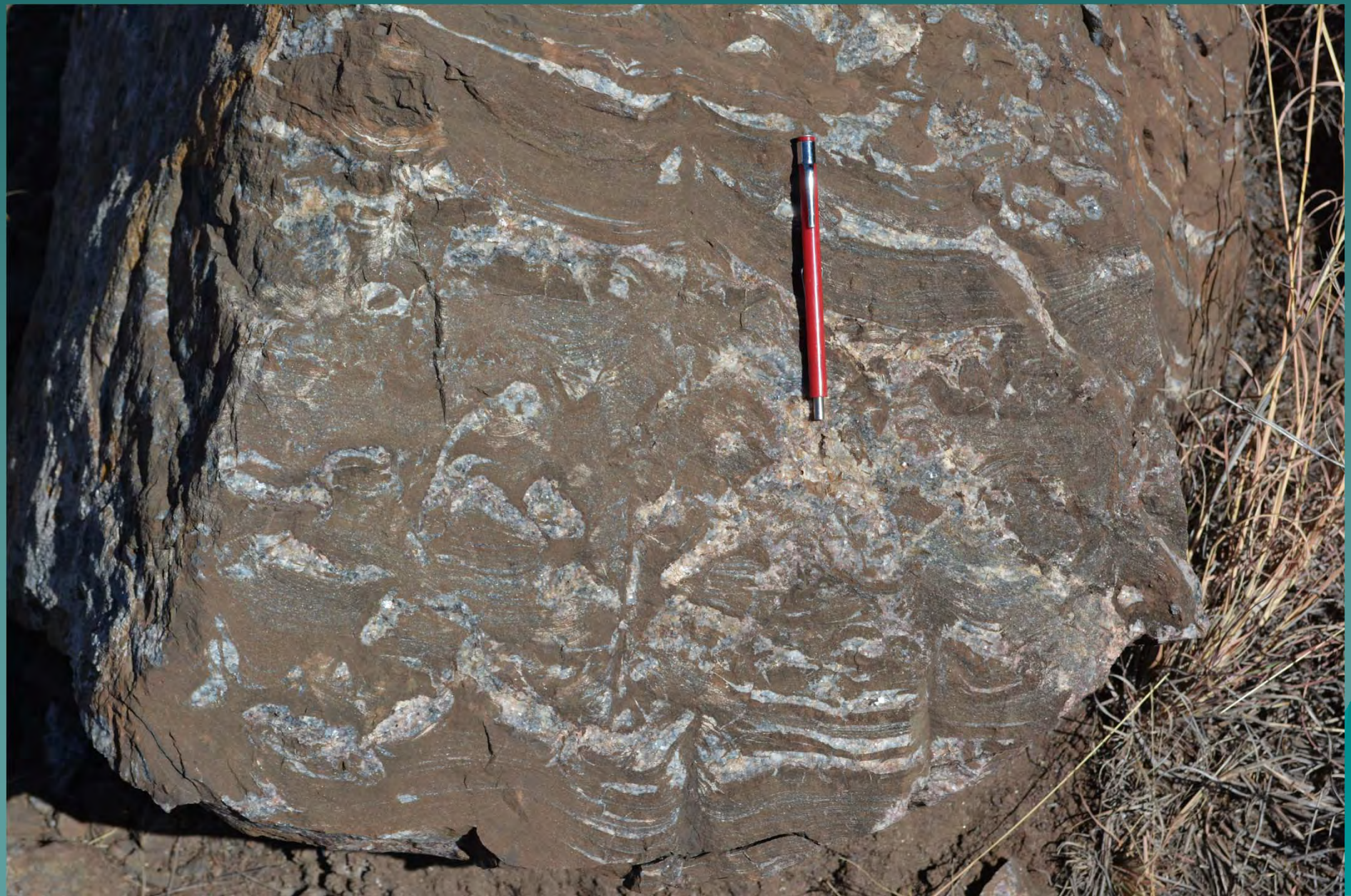
Associated with stromatolites and dewatering structures

Low temperature (no obvious wall-rock alteration)

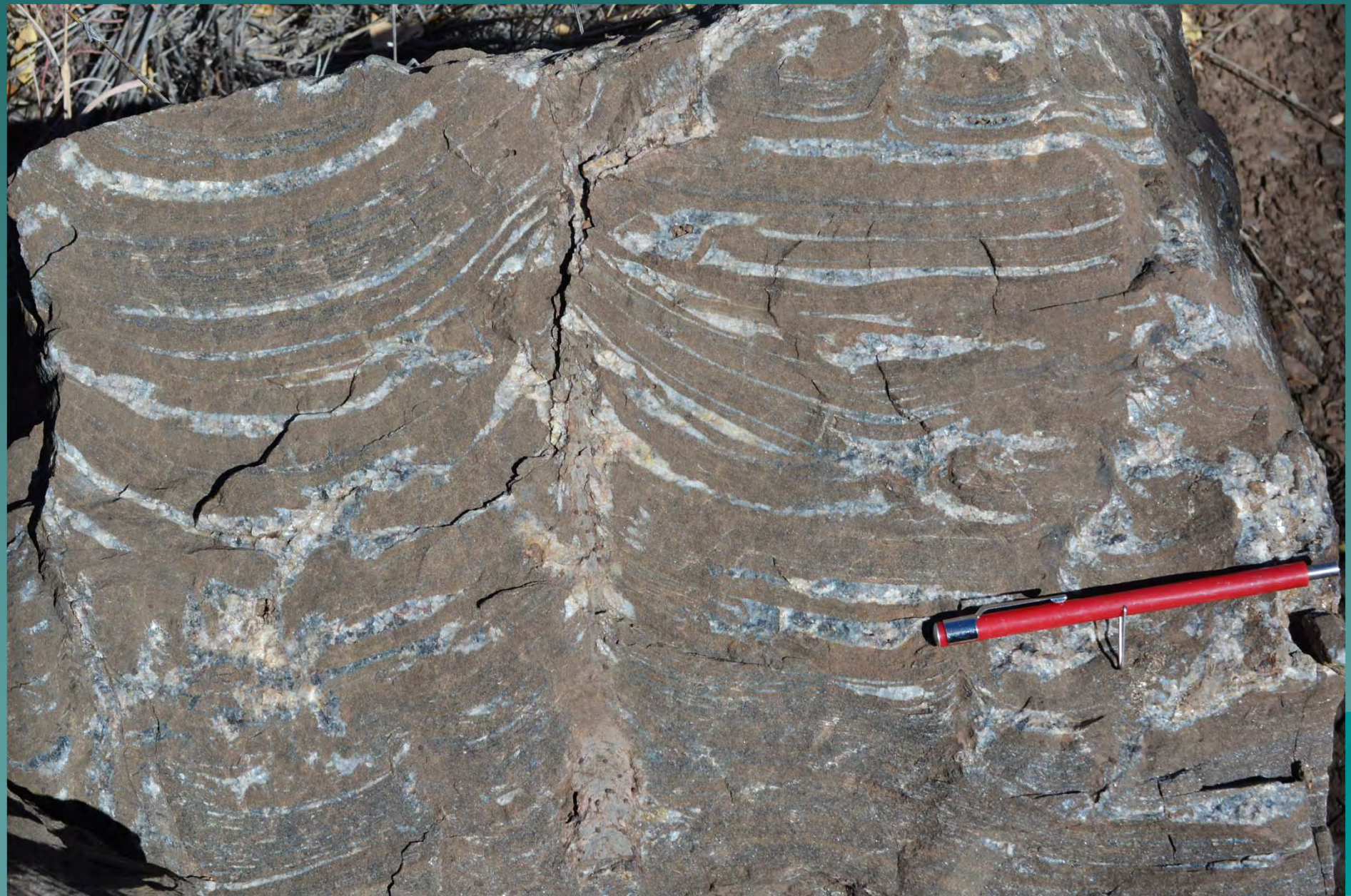
Some high grade pipes of massive fluorspar

Some pipes with disseminated zinc

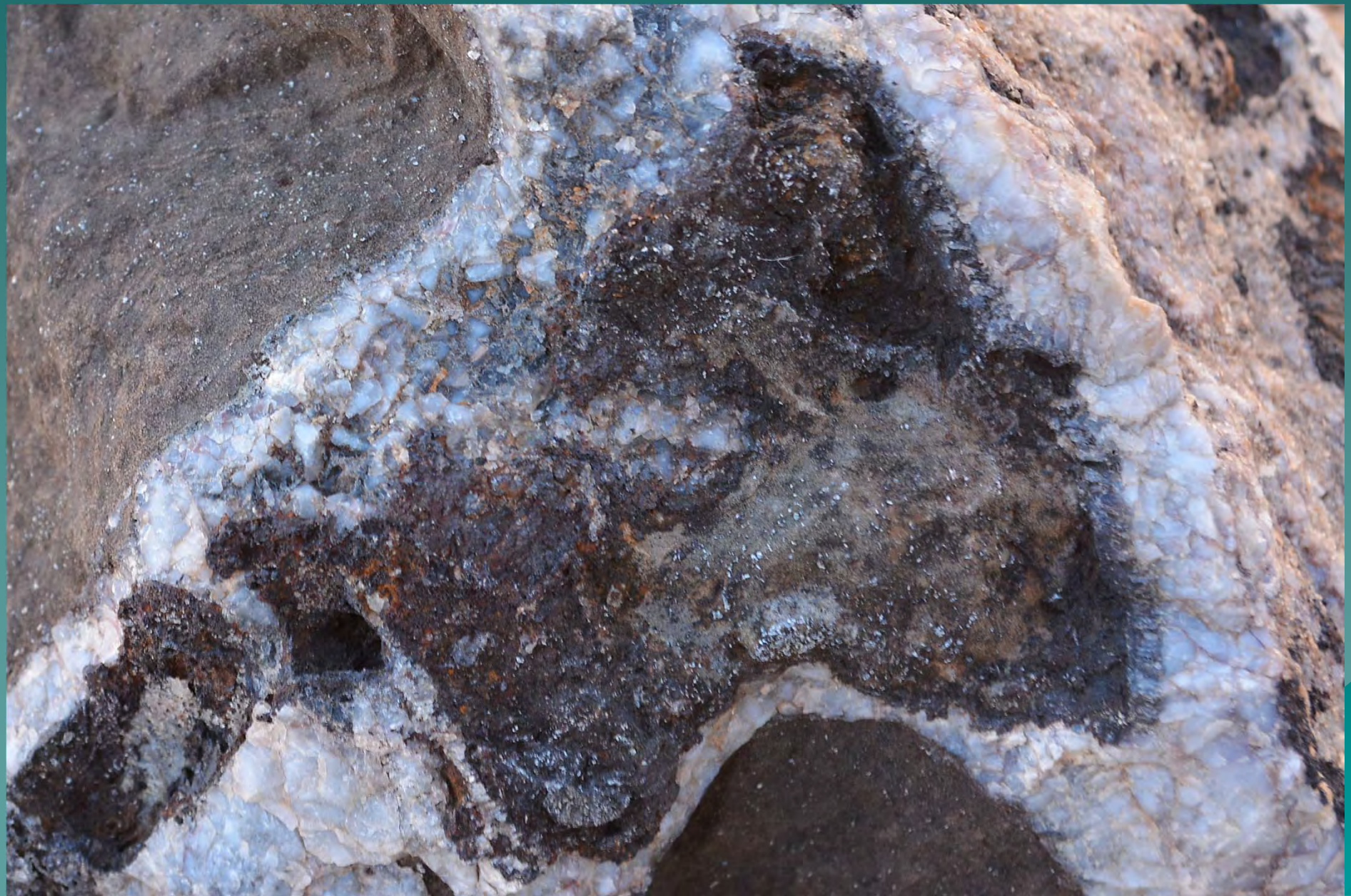
Stratabound Zeerust Fluorite



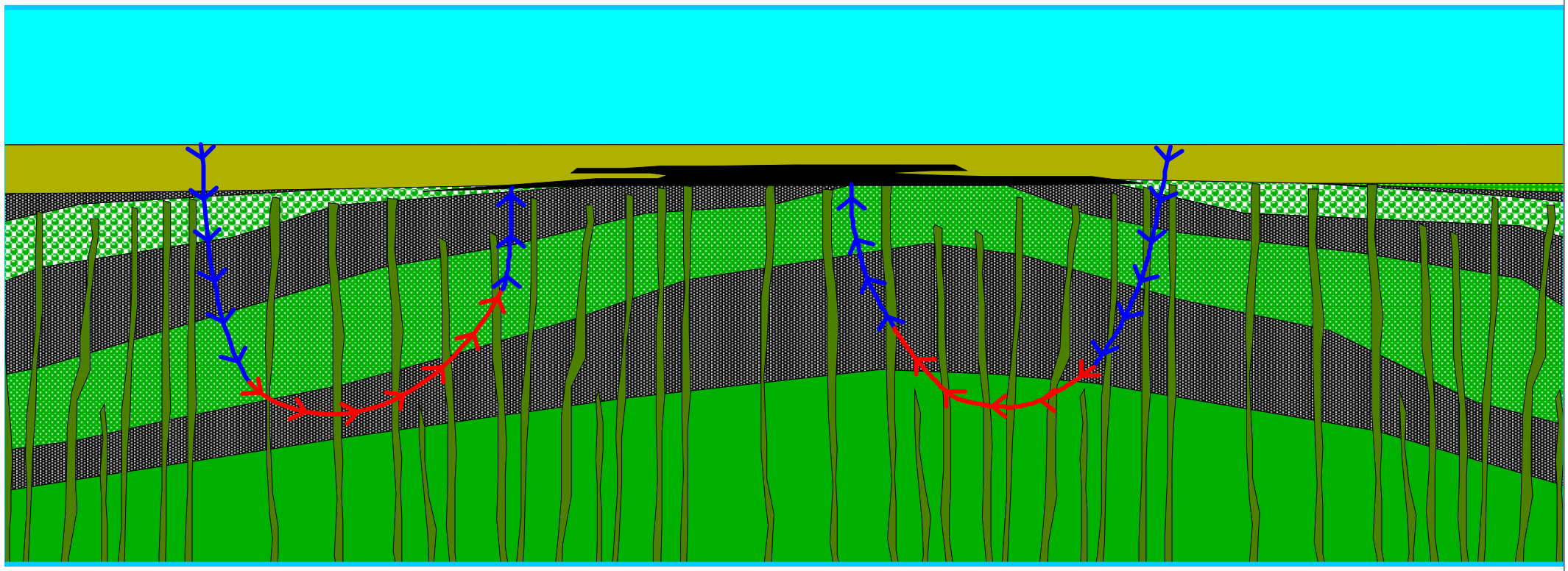
Volcanic associations Sedimentary Fe and Mn



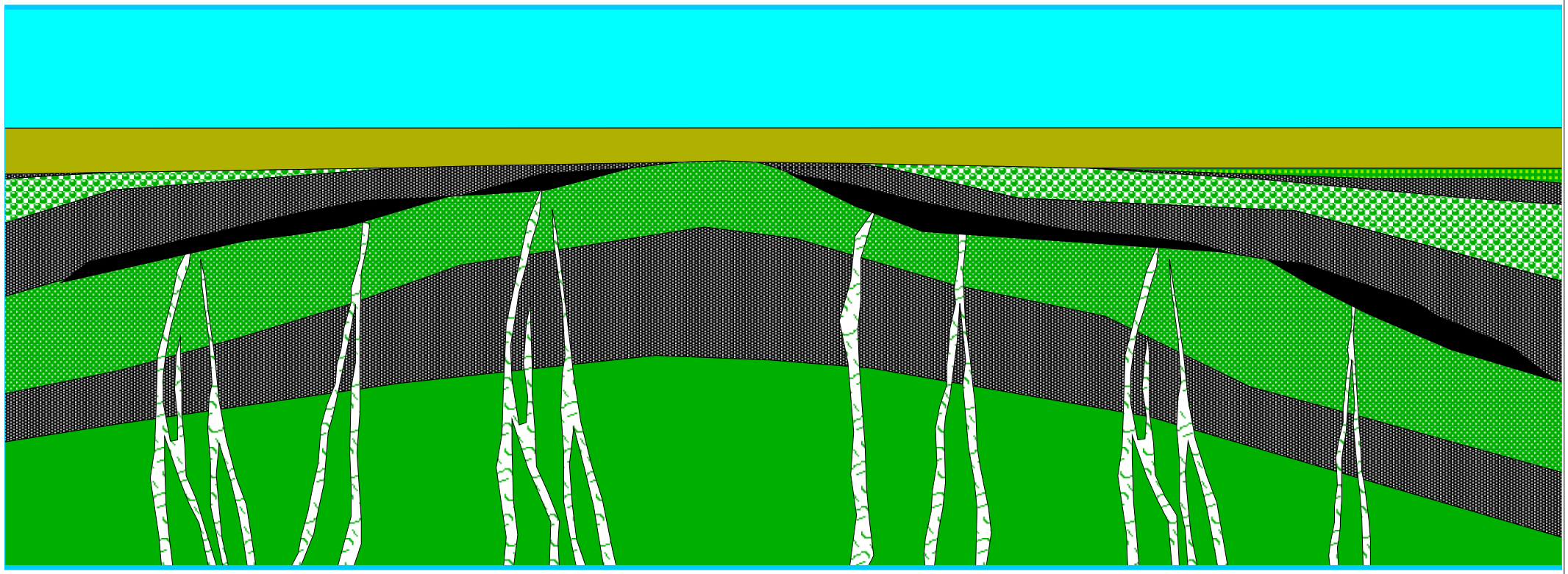
Stratabound Mississippi Valley Fluorite



Volcanic associations VMS



Volcanic associations VMS



Deposit styles

Brines

Li

Rare Earths

Modern Systems

Salton Sea 25 to 30% dissolved solids including Cu 8ppm, Pb 84ppm, Zn 790ppm

Red Sea SiO_2 and Cu major components

Taupo Zone New Zeeland

Mid-Ocean Black Smokers

Some aspects of Hydrothermal Mineralisation