

Century Zinc Deposit

Sulphides, Hydrocarbons, Source Beds

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SMEDG - 2007

WHY ZINC ?

- Tied to use of steel (protection against corrosion)
- Increasing demand and production
- Depletion of known ore reserves
- No significant discoveries in last 17 years

Major new zinc discoveries needed now to meet growing demand.

WHY CENTURY DEPOSIT ?

- Formed in shaly sediments during diagenesis.
- Sphalerite is intimately associated with bitumen.
- Concept used by petroleum geologists:
'Source Bed – Migration – Entrapment under a Seal'
may be applicable in search for Century type zinc deposits.

CENTURY ZINC DEPOSIT

Discovered by CRA Exploration

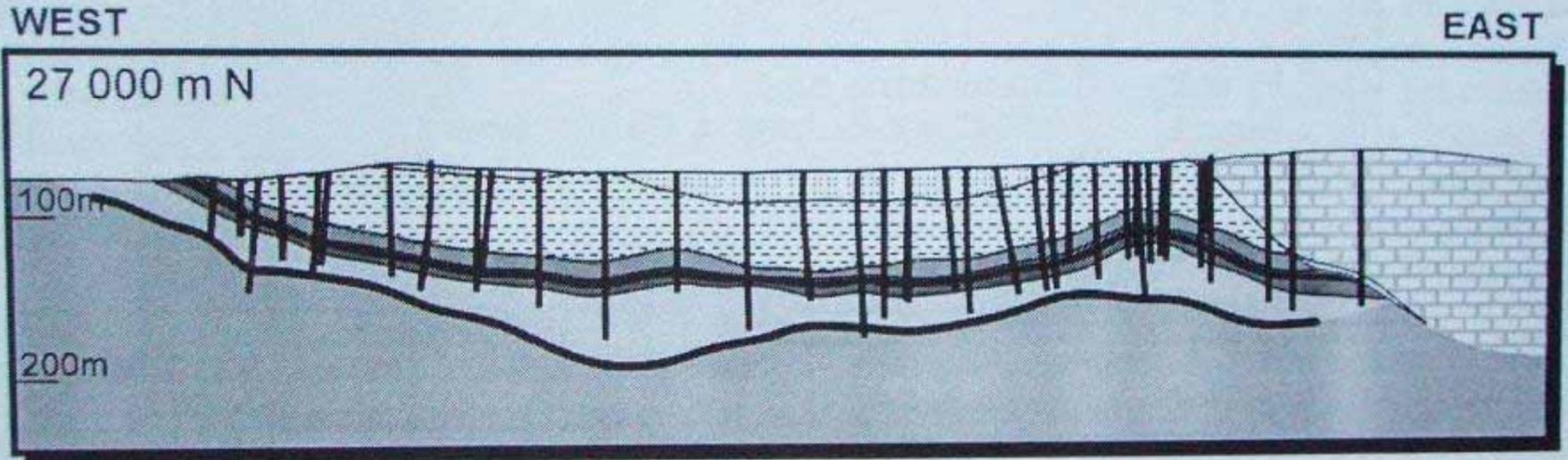
- Discovery in 1990 by CRA Exploration
- Result of systematic search for large strata-bound zinc-lead-silver deposits
- Zinc search commenced in 1948 by drill testing Dugald River Gossan (60 years from first drill intersections to a full feasibility study)
- Board of CRA Ltd. maintained a strong commitment to exploration right up to the merger with RTZ in 1996.
- A complement of 115 geologists and at least 9 exploration bases maintained through all downturns.

CENTURY ZINC DEPOSIT - Overview

- Original resource 105 million tonnes @ 12% Zn
- Entire resource amenable to open cut
- **Century is:**
 - **the second largest mine in Australia by revenue**
 - **made the largest profit**

CENTURY ZINC DEPOSIT GEOLOGICAL SECTION

G.C.Broadbent & A.E.Waltho 1998 (AusIMM Monograph 22):



CENTURY ZINC DEPOSIT - typical drill log

DD91LH231

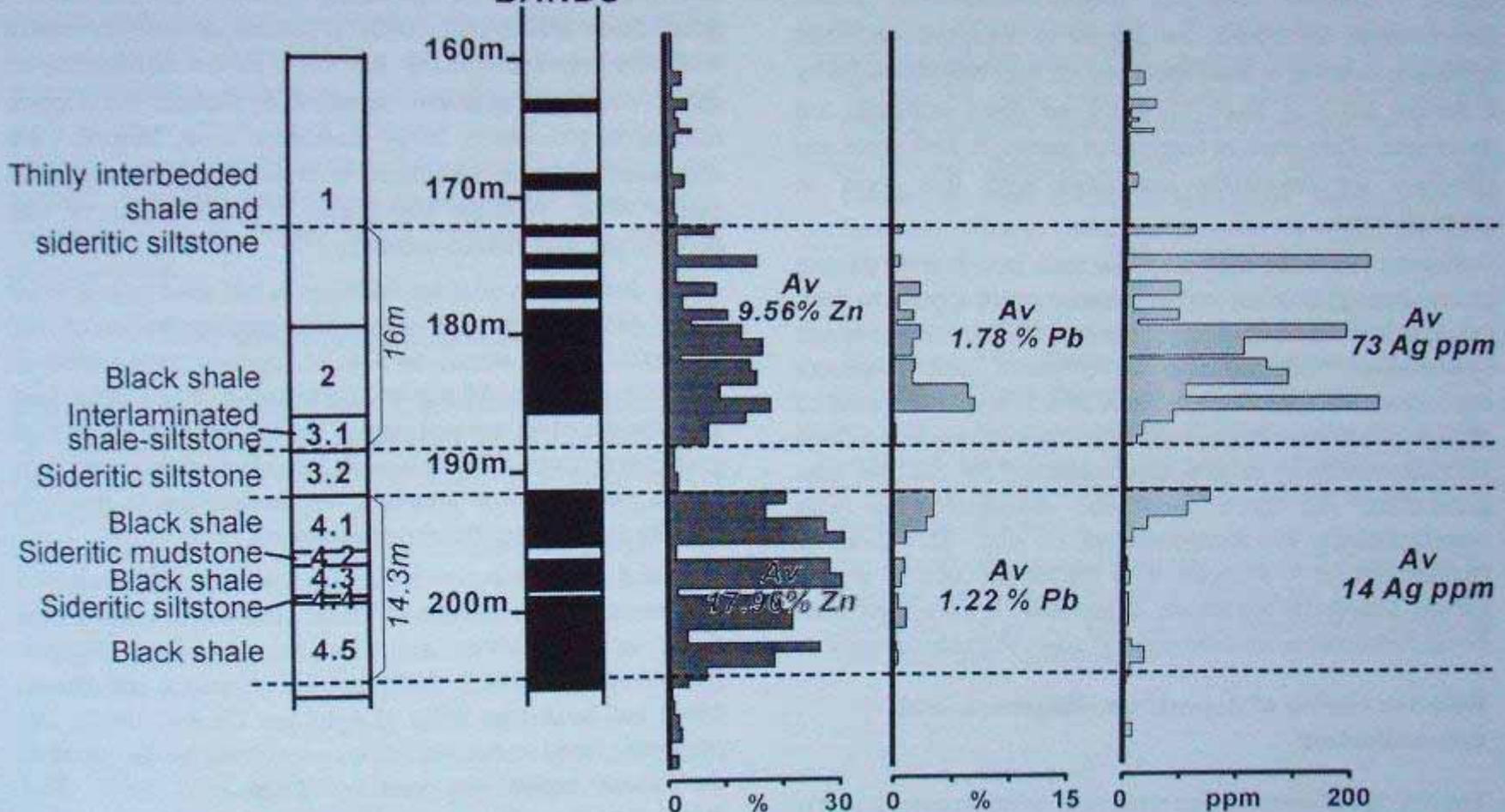
UNIT

SHALE BANDS

ZINC

LEAD

SILVER



CENTURY ZINC DEPOSIT – open cut



CENTURY ZINC DEPOSIT – exposure of ore

(only minor visual difference between mineralised and barren shale)



CENTURY ZINC DEPOSIT – lumps of ore

(sphalerite & bitumen rich bands - light colour)



CENTURY ZINC DEPOSIT – typical ore

(sphalerite & bitumen rich bands - light colour)



CENTURY ZINC DEPOSIT

Localised 'soft sediment' deformation caused partial remobilisation of sphalerite and galena (on right side)



CENTURY ZINC DEPOSIT

Localised 'soft sediment' deformation caused partial remobilisation of sphalerite and galena



CENTURY ZINC DEPOSIT

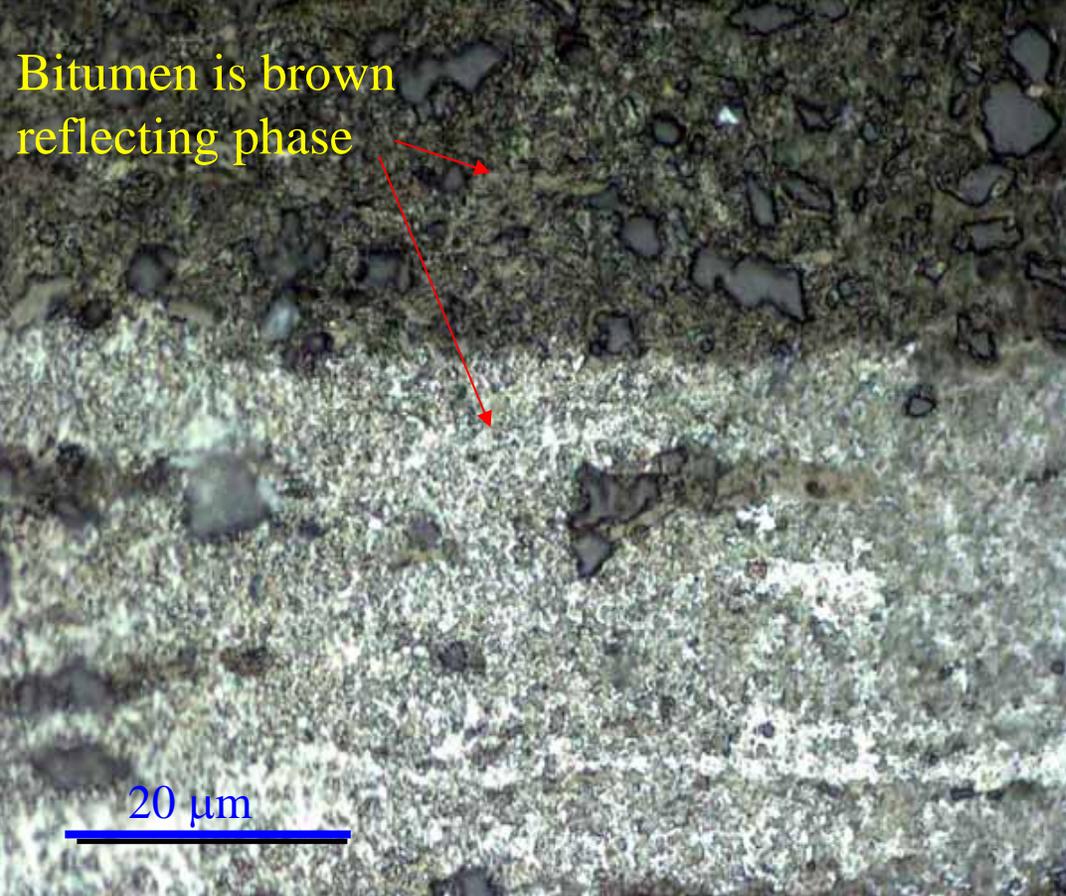
G.C.Broadbent & A.E.Waltho 1998 (AusIMM Monograph 22):

- “intimate association of sulphides, siderite and hydrocarbons”
- “conventional SEDEX model can not be used to explain macro and microscopic observations”
- “timing relationships between stylolite development, sulphide deposition and compaction of shaly sediment point to a syn-diagenetic replacive origin”

Association of Sphalerite with Bitumen

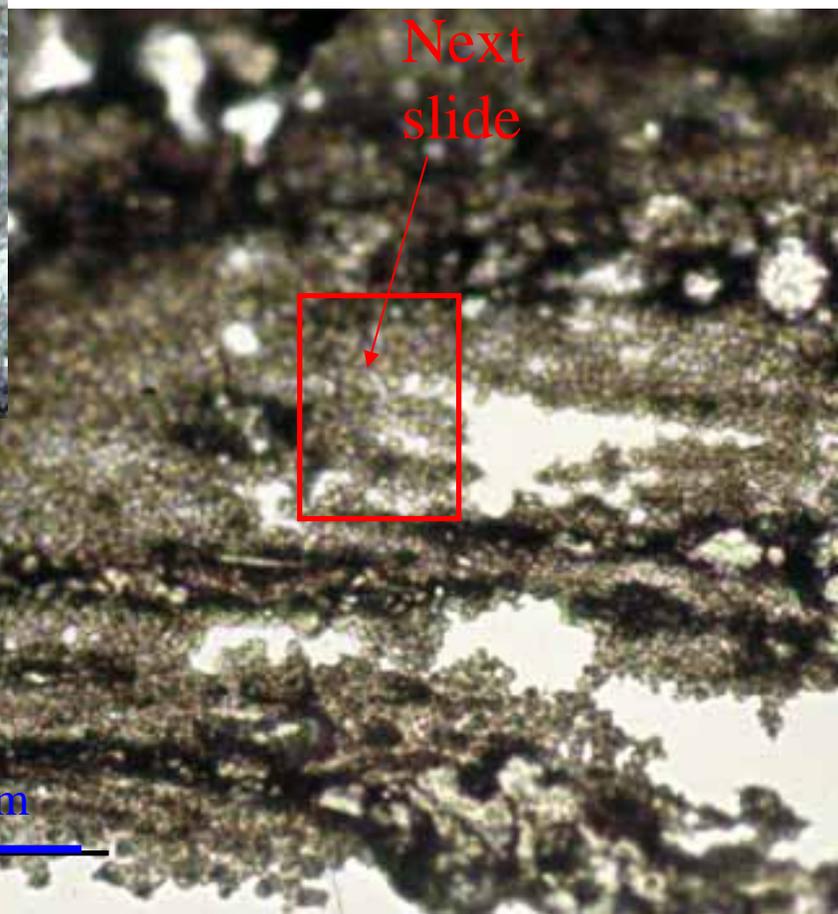
- **In Century deposit the bitumen is present in large quantities and is intimately associated with sphalerite across the entire deposit.**
- **A major proportion of sphalerite grains has tiny bitumen inclusions.**
- **There are also tiny ‘inclusions’ of sphalerite in thin layers of bitumen.**

Mixture of sphalerite and bitumen is one of key characteristics of Century deposit.



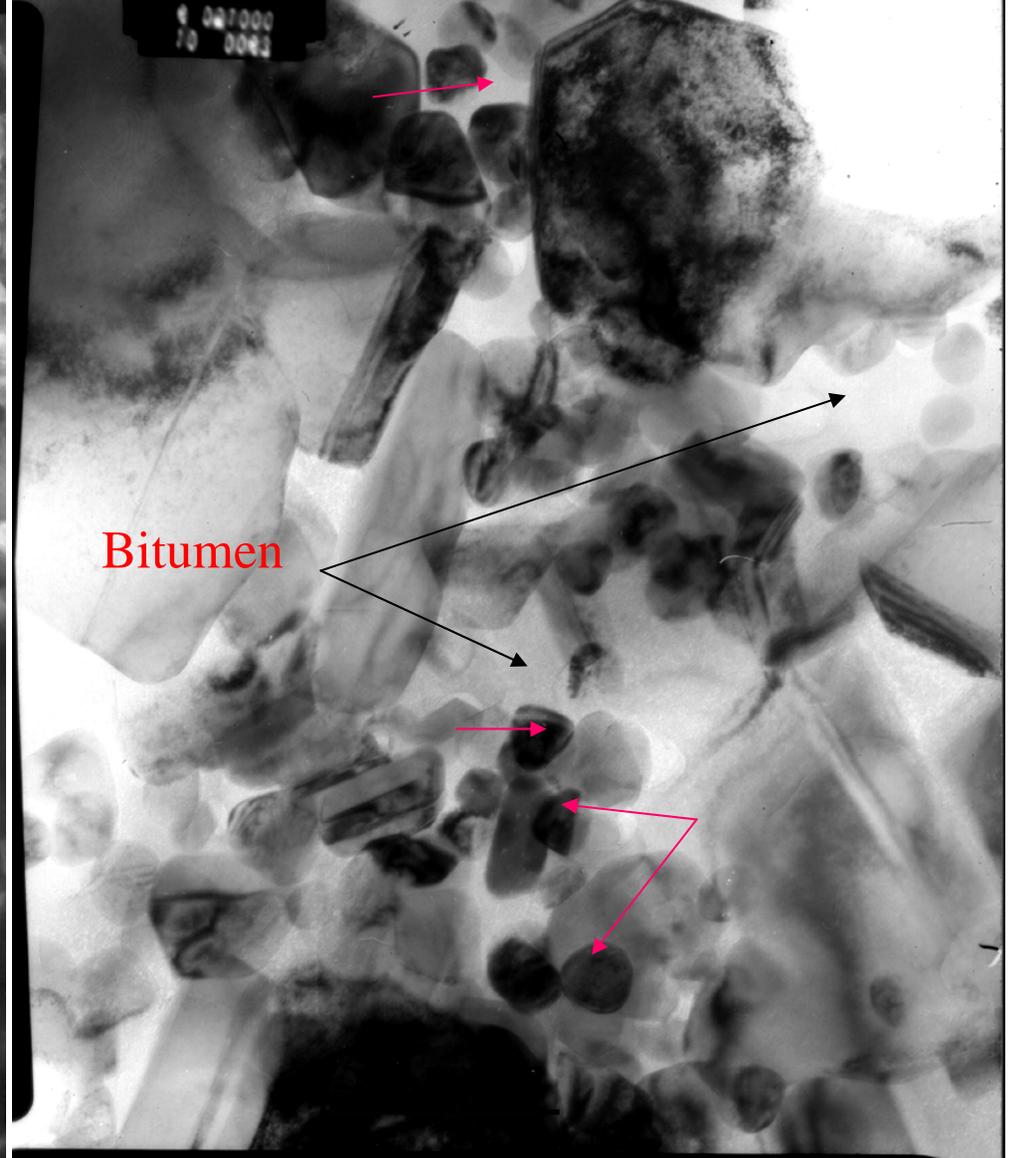
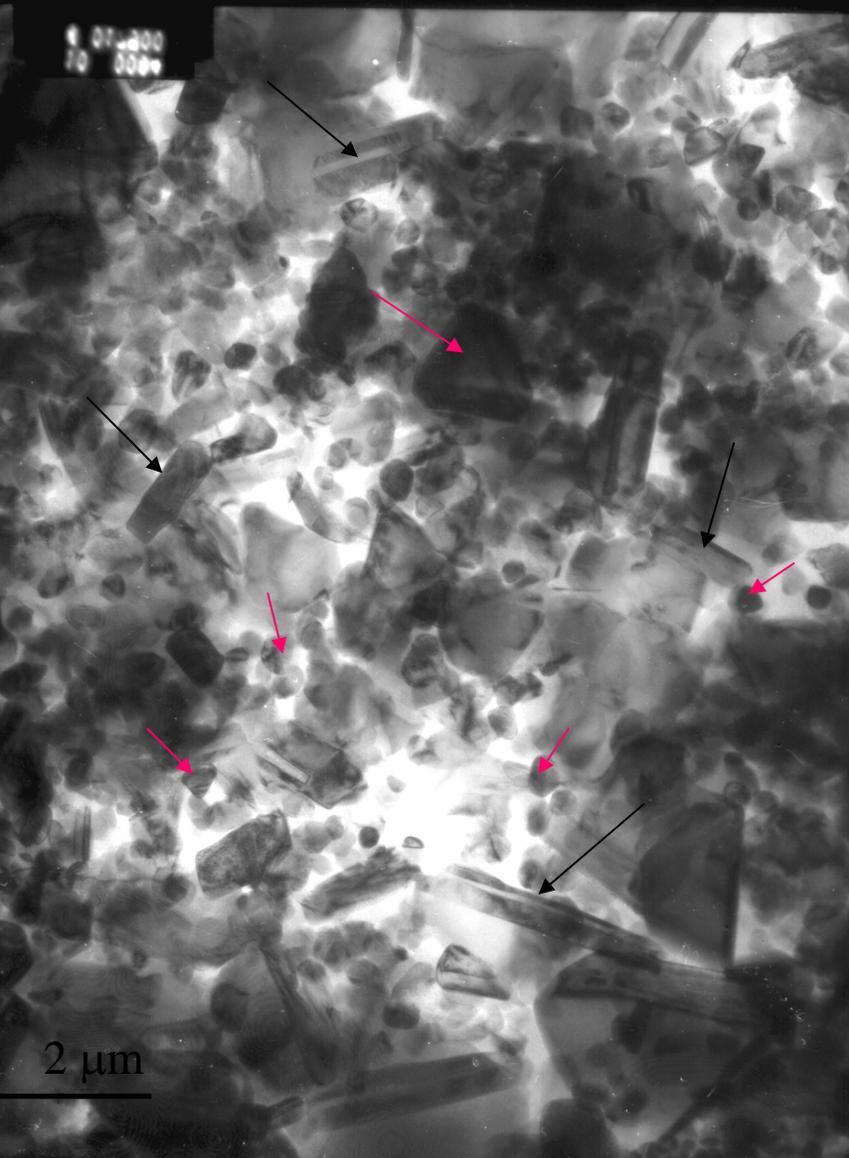
Bitumen is brown reflecting phase

Century - highly bituminous (porous) sphalerite laminae in siltstone - reflected light image



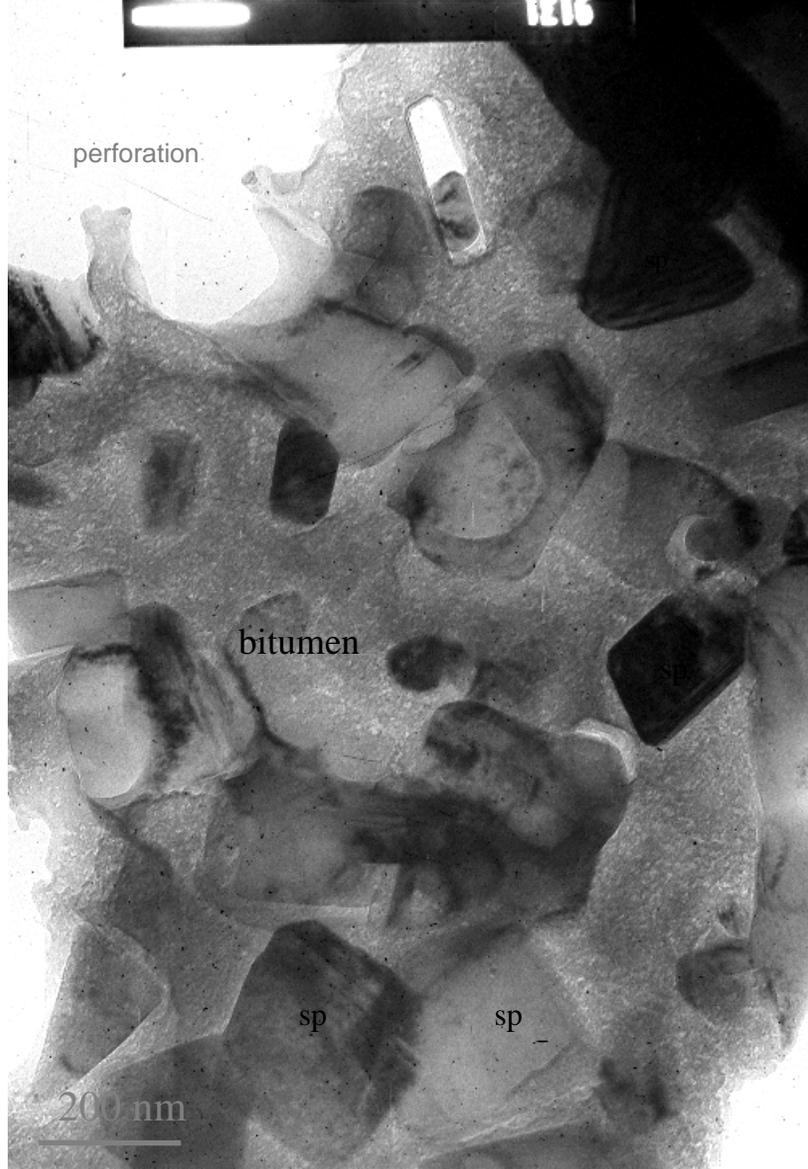
Next slide

Portion of TEM foil - electron transparent bituminous sphalerite laminae - transmitted light



Century “Porous” sphalerite –300kV TEM images “Porous Sphalerite” is not an appropriate description – really myriads of crystallites of ZnS “floating” in bitumen

Slide supplied by **Stafford McKnight, Ballarat University**



Highly bituminous “porous” sphalerite

– Century TEM x50,000

Slide supplied by **Stafford McKnight, Ballarat University**

Association of Sulphides with Bitumen

- **Bitumen is present in majority of sediment hosted sulphide ore deposits.**
- **This fact may be recorded during ore microscopy but is rarely discussed in published papers.**

Mixture of sulphide and bitumen is commonly encountered, however few studies of ore genesis have taken this fact into consideration.

DISCOVERY OUTCROP

1998 photo (before drilling)



Century, late 1989
Century outcrop before it was drilled

DISCOVERY OUTCROP

Truck parked on discovery drill site (1990)



Test Pit at Discovery Outcrop



Test Pit at Discovery Outcrop – PHOTO TAKEN IN 2005

(visually it is difficult to distinguish barren and mineralised shale)



Key Success Factors in Century Discovery (1990)

- Silver veins (discovered in 1890)
- Surface Geochemical Sampling
- Anomalous zinc values in a few soil samples
- Anomalous zinc and silver values in a few limonitic rock samples from outcrop
- Drill testing a new type of target
- RC drilling and systematic assaying of entire drill hole (high zinc assays were a pleasant surprise)
- **Surface geochemical zinc anomalism is 'subtle'.**
- **Signs of mineralisation are rather difficult to recognise in outcrop.**

EXPLORATION FOR CENTURY TYPE ZINC DEPOSITS - 1.

- Gentle dip of mineralised strata (like coal deposits).
- Outcrop is visually not attractive.
- Very little pyrite is present - no gossan to be expected!
- Lead and silver content is low – there may be no old workings as prospectors were not interested in zinc.
- Electrical geophysics do not detect sphalerite.

Many Century type deposits remain to be discovered.

EXPLORATION FOR CENTURY TYPE ZINC DEPOSITS – 2.

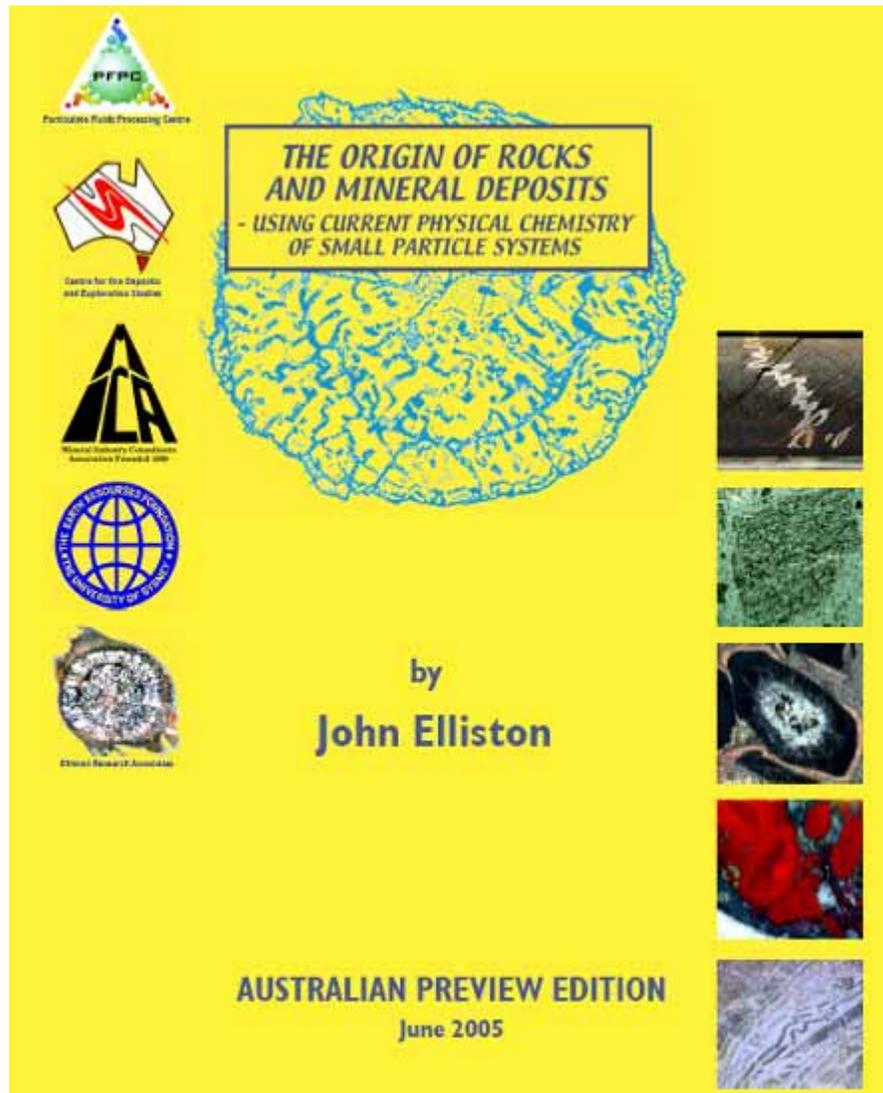
- Shaly sediments extend over areas as large as 100 000 square kilometres.
- Low level zinc stream sediment and soil anomalies are widespread.

What are area and target selection criteria ?

Which of the characteristics of Century deposit should be used in formulation of area and target selection criteria?

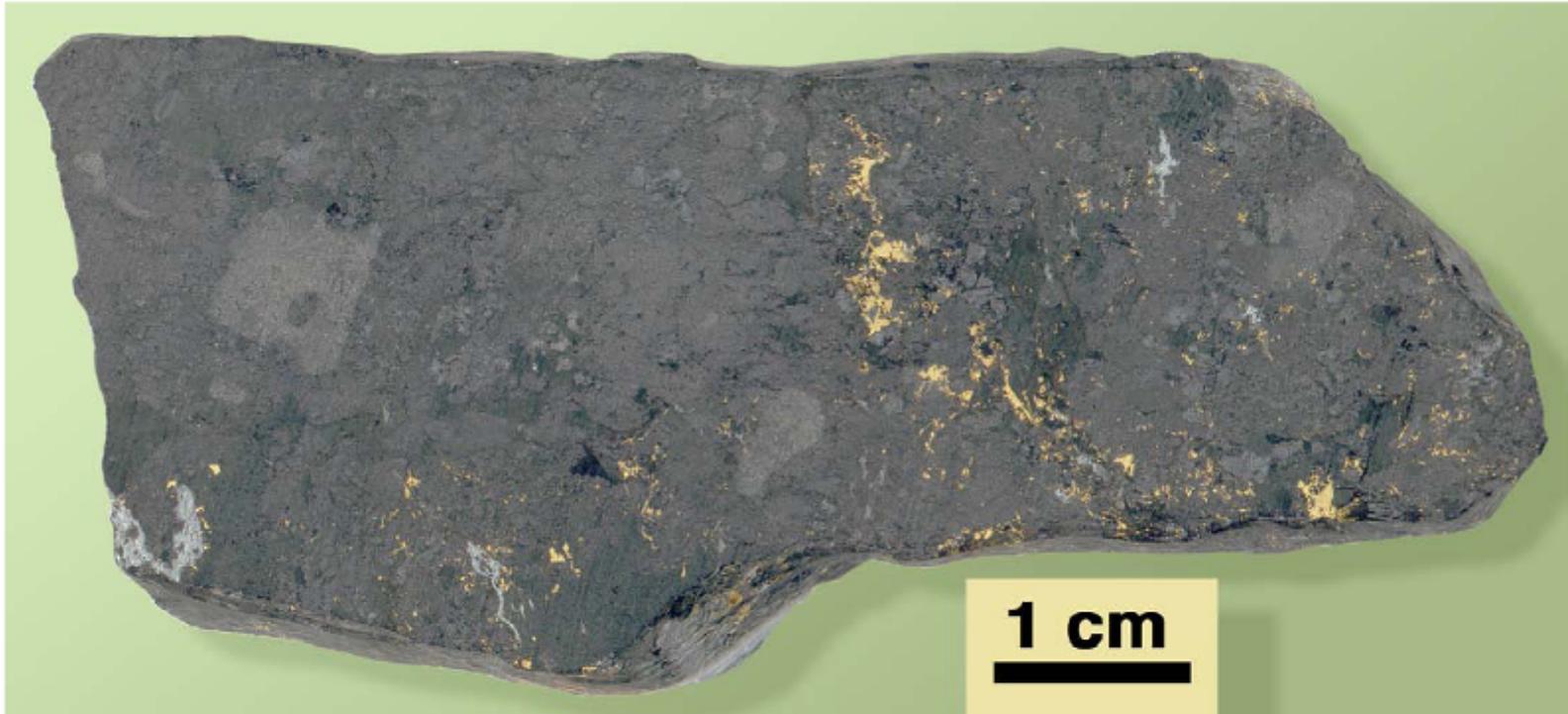
Depends on interpretation of ore genesis!

After 44 years of intensive research into role of colloidal size sulphide particles John Elliston published his work



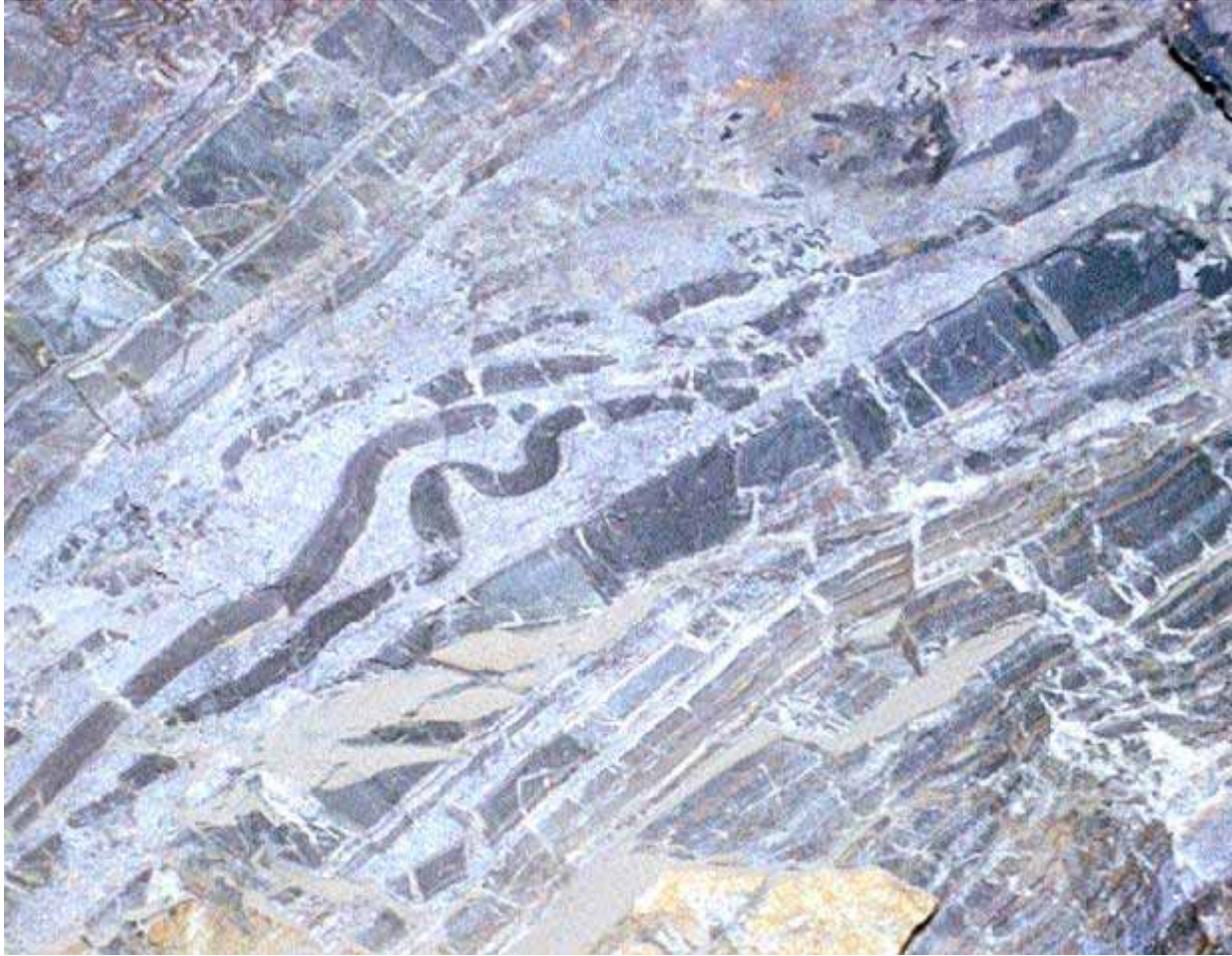
example of illustrations from John Elliston's book

Figure 3.40



Metallic gold in high grade ore from the Juno Mine at Tennant Creek occurs in an intrusive magnetite breccia body. The magnetite has crystallised from fractured **lepidocrocite** gel [FeO(OH)]. Dark chlorite, bismuth, and bismuth sulphide also occur in the specimen.

example of illustrations from John Elliston's book



example of illustrations from John Elliston's book



FIGURE 36. Concretionary sphalerite oolites in the Iokun'zh colloform ore lens have irregular shapes. There are composite oolites, deformed and mutually impinging oolites.

GENESIS OF SULPHIDE ORES

John Elliston studied processes taking place in sediments during diagenesis, with focus on mobility of metals in colloidal sulphide form.

Migration / mobilisation of colloidal sulphides and gangues only takes place if the source sediment has been 're-textured'.

His concepts of formation of ore bodies include:

- replacement of host sediment by colloidal sulphides,
- growth of colloidal sulphide concretions,
- injection of pasty mixture of colloidal sulphides and gangues to form veins of massive lodes,
- multi-stage remobilisation of colloidal sulphides and gangues prior to crystallisation

Formation of Ore Deposits during Diagenesis:

1. Source bed with colloidal sulphides
2. 'Maturation' of hydrocarbons
3. 'Retexturing' of sediment
4. Migration / mobilisation of hydrocarbons and colloidal sulphides
5. Entrapment / concentration in concordant structures under a seal
6. Remobilisation into concordant and discordant structures

Such concepts have been used successfully in search for hydrocarbons. They can also be used in search for zinc.

Colloidal particles of sulphides migrate with hydrocarbons and connate brines (K, Na and Cl ions).

EXPLORATION FOR CENTURY TYPE ZINC DEPOSITS – 3.

Area & Target Selection Criteria:

- Thick package of organic matter bearing (=reduced) shaly sediments with some carbonate component.
- Right degree of 'maturation' and 'retexturing' ('matured' and 'retextured' to such degree that sphalerite as well as hydrocarbons have migrated out of source beds).

Elevated temperature alone will not cause migration of sulphides from source bed – movement / 'retexturing' is also needed.

**A sulphidic shale with 1000ppm Zn :
A 'would-be' Source Bed which never released its sulphides**

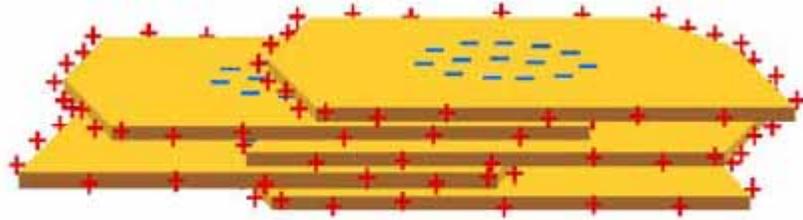
If sulphides have remained in the source bed, they give rise to a laterally very extensive geochemical anomaly of 'black shale' type.

This means that:

- **sulphides have not migrated / mobilised out the source bed and into a trap,**
- **one should not expect ore deposits in such setting.**

When does a Source Bed release its sulphides ?

When it is 'retextured' to such degree that colloidal size sulphide particles (and Na, K and Cl ions) have been desorbed from sediment particles and started migrating in (highly saline) intergranular fluid toward traps.



Desorption is staged which explains paragenetic sequence observed in metallic deposits (see John Elliston's book for details).

Retexturing to release sulphides from Source Bed

from John Elliston's book

Figure 3.33

Some of the lensoid fragmental rocks formed by shearing soft sediments in the Orlando slip complex contained re-mobilised mud between the pellets. This material contains porphyry-like nodules of quartz, chert, clay and feldspar.



Discordant Silver-Lead-Zinc-Bitumen Veins (Historic Lawn Hill Mining Field)



Vertical quartz – sulphide – bitumen veins cross-cutting gently dipping strata!

Concordant versus Discordant Mineralisation

Traditionally:

- Concordant mineralisation was classified as “syngenetic” / “exhalative”.
- Discordant mineralisation was classified as “epigenetic” (emplaced long after host sediments had been lithified).

However:

- **Due to multi-stage remobilisation, sulphides and gangue minerals can form both concordant and discordant mineralised bodies.**

Opportunities for major concordant zinc discoveries in areas neglected due to presence of vein mineralisation

- **Traditionally areas with discordant (vein, breccia, etc) zinc mineralisation have not been explored for concordant / syngenetic exhalative deposits.**
- **However in 1989 – 90 Century deposit has been discovered in Lawn Hill silver-lead vein mining district.**

CONCLUDING REMARKS

- Large volume of source beds is needed to get a large deposit.
- Source beds need to be 'retextured' to release sulphides and hydrocarbons, as well as Na, K and Cl ions.
- Remobilisation of sulphides and hydrocarbons takes place in highly saline intergranular fluids during diagenesis.
- Diagenesis is the best time for mineralising processes because the sediment is semi-soft, containing intergranular fluids.
- Graeme Broadbent and Andy Waltho proposed syn-diagenetic origin for Century. How it works in detail is explained in John Elliston's book.