Lau and Manus Basins

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List of twelve key references
7. Lau and Manus Basins
Global comparison of massive sulfides
GEODE

Team:
Peter Herzig

7.1. Age and tectonic/structural setting

7.1.1 What is the age of your VMS district?
- Extent, type and precision of geochronolgy? (belt scale and deposit scale)
- Palaeontological control

Lau Basin
Recent seafloor.

Manus Basin
Recent seafloor.

7.1.2 What is the current interpretation of the tectonic setting of your VMS district? (include an timesequence diagram if available)

Lau Basin
Intraoceanic back-arc basin.

Manus Basin
Intraoceanic back-arc basin.

7.1.3 What is the tectonic interpretation based upon:
- structural mapping and interpretation? (quality of mapping?)
- gravity and/or magnetic data (has it been used?)
- any seismic sections?
- chemistry of volcanic rocks? What geochemical-tectonic classification was used?

Lau Basin
Seafloor observation.

Manus Basin
Seafloor observation.

7.1.4 Is there a comprehensive and high quality database of volcanic geochemistry to assist with tectonic interpretation?
- how many whole-rock/trace analyses on least-altered rocks?
- type and quality of trace element data?
- what isotope data are available?

Lau Basin
Data is available, but has not been combined into a database. Several dozen to hundreds of samples have been analyzed throughout the basin. The quality of the data is usually good. XRF, ICP, INAA have all been used. Strontium, neodym, lead and oxygen isotope analyses have been performed by various authors.

Manus Basin
Only few data available.
7.1.5 *Have the district-scale and deposit-scale ore-fluid plumbing structures been identified? Size of structures? How were they defined (mapping?, alteration?, aeromagnetics? geochemistry? Isotopes?)*

Lau Basin
No.

Manus Basin
No.

7.1.6 *Have detailed structural studies of the deposits been undertaken? Which deposits?*

Lau Basin
No.

Manus Basin
No.

7.1.7 *What further research is needed to improve the tectonic interpretation?*

Lau Basin
Tectonic setting is quite obvious, however, geophysical cruises are still valuable for regional scale and also to obtain detailed information on the deposits.

Manus Basin
Tectonic setting is quite obvious, however, geophysical cruises are still valuable for regional scale and also to obtain detailed information on the deposits.

7.1.8 *List key references*

Lau Basin

Manus Basin

7.2 *Volcanic architecture*

7.2.1 *What are the scales of geological maps available for the district and the deposits? Has a comprehensive systematic stratigraphy been established for the district?*

Lau Basin
Maps are only available as regional scale bathymetric maps. Cartoons are available on a deposit scale. Stratigraphy is not established in the imidiate vicinity, however, ODP drilled several sites in the Lau Basin.

Manus Basin
Maps are only available as regional scale bathymetric maps. Cartoons are available on a deposit scale. Stratigraphy is not established.

7.2.2 How do the VMS deposits relate to volcanic facies? Provide some sketch diagrams if available. Do the VMS deposits occur at a single stratigraphic position? Do the VMS deposits occur in proximal or distal volcanic facies? Percentage of volcaniclastic rocks versus coherent flows or intrusions?

Lau Basin

All deposits are related to proximal volcanics. Deposits occur at a single stratigraphic position for each district (e.g., Valu Fa Ridge and Northeastern Lau Basin).

Northeastern Lau Basin

Inactive deposit in axial region of active spreading ridge.

Valu Fa Ridge

White Church

Several deposits at the top and flanks of the ridge.

Vai Lilia

Fault controlled deposits occupies ridge crest. Andesitic to dacitic lavas

Hine Hina

Smaller deposits with extensive alteration of andesitic volcanics. All deposits are related to proximal volcanics. Deposits occur at a single stratigraphic position for each of district (e.g., Central and Eastern Manus basin).

Manus Basin

Vienna Woods

Deposit at 2km wide axial rift graben of spreading center in an area of abundant pillow lavas.

Pacmanus

Deposit situated at crest of prominent Pual Ridge with associated dacite flows and dome structures.

Desmos

Caldera of basaltic/andesitic volcano.

7.2.3 What is the composition (rhyolite?, basalt?) of the VMS host package? Is there a change in volcanic composition at, or close to, the ore position?

Lau Basin

Bimodal volcanism dominated by andesitic to rhyolitic volcanics occurs along the Valu Fa Ridge. VMS deposits are related to the occurrence of dacitic rocks. Basalts are the dominating host rocks of the Northern Lau basin. Information is scarce in this area.

Manus Basin

The sulfides at the Vienna Woods site (Central Manus Basin) are hosted by basalts. The Pacmanus site (Eastern Manus Basin) is hosted by highly vesicular dacite.

7.2.4 What is the interpreted range of water depth during deposition of the volcanic succession, and immediate host rocks? What criteria were used to estimate water depth (e.g., volcanic facies, sedimentary structures, fossils, fluid inclusions)?

Lau Basin

Water depth in the vicinity of the deposits is 1700 to 2000 m at the Valu Fa Ridge and ~2000 m near the
Kings Triple Junction (also named Mangatolu Triple Junction).

Manus Basin
Water depths are ~2500 m at the Vienna Woods site and ~ 1650 m at the Pacmanus site.

7.2.5 What further research is needed to define the relationship between ore formation and volcanic architecture?

Lau Basin
Drilling information is needed.

Manus Basin
Drilling information is needed.

7.2.6 List key references

Lau Basin

Manus Basin
see above and additionally:

7.3 Styles of ore deposits

7.3.1 Provide a table of tonnes and grade for major deposits (>1 million tonnes) (include economic and sub-economic or barren massive sulfides). How many additional deposits of less than 1 million tonnes are known in the district?

Lau Basin
Open.

Manus Basin
Open.

7.3.2 What is the degree of metamorphism, deformation and recrystallization in the ores. Does it vary from deposit to deposit in the district?

Lau Basin
7.3.3 What VMS deposit types occur within the belt (eg polymetallic Zn-Pb-Cu-type, Cu-Zn-type, Cu-type, Au-only, barite-only, pyrite-only)? Give a cartoon model of each type present, showing simple geology, morphology of the deposit and metal zones. Do not use genetic classifications such as kuroko type or Cyprus type, but use metal content and ratios – Cu/(Cu+Zn) and Zn/(Zn+Pb). (eg. Large, 1992 : ECON. GEOL. V87, p 473).

Lau Basin
Polymetallic mounds and chimneys

<table>
<thead>
<tr>
<th>Location</th>
<th>Cu/(Cu+Zn)</th>
<th>Zn/(Zn+Pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valu Fa Ridge</td>
<td>0.17</td>
<td>0.98</td>
</tr>
<tr>
<td>Northern Lau</td>
<td>0.17</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Manus Basin
polymetallic mounds and chimneys

<table>
<thead>
<tr>
<th>Location</th>
<th>Cu/(Cu+Zn)</th>
<th>Zn/(Zn+Pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vienna Woods</td>
<td>0.10</td>
<td>0.97</td>
</tr>
<tr>
<td>Pacmanus</td>
<td>0.29</td>
<td>0.94</td>
</tr>
</tbody>
</table>

7.3.4 Are stringer zones present or economic? What is their mineralogy? Are there any deposits that comprise only stringer sulfides?

Lau Basin
Stringer zones have been observed and sampled. Chalcopyrite seems to be more important in the stringer than in the massive sulfides. Only limited information.

Manus Basin
No information.

7.3.5 What are the major textures in the massive sulfides – massive featureless, banded, brecciated? Are these textures interpreted to be primary or deformation-related. Key evidence?

Lau Basin
Massive and chimneys/primary.

Manus Basin
Massive and chimneys/primary.

7.3.6 Did most deposits form on the seafloor or by replacement below the seafloor or a combination of both? Key evidence? If sub-seafloor, how far below the seafloor? Evidence?

Lau Basin
The majority of the sulfides is believed to occur above the seafloor, but information about the third dimension is lacking.

Manus Basin
The majority of the sulfides is believed to occur above the seafloor, but information about the third dimension is lacking.
7.3.7 Did the seafloor deposits form in brine pools, or as mounds, or are both types represented, or did they form by some other mechanism? Key evidence? Is there general agreement on the mechanism of formation?

Lau Basin
Deposits formed as mounds with additional single chimneys or chimney groups.

Manus Basin
Deposits formed as mounds with additional single chimneys or chimney groups. Mineralization at the Desmos caldera is disseminated sulfide impregnation.

7.3.8 List key references for each deposit.

Lau Basin
Valu Fa Ridge

Northern Lau Basin

Manus Basin

7.4 Exhalites

7.4.1 Are “exhalites” (Fe, Si or Mn, units) present at the same stratigraphic level as the ores? Are other styles of ore-equivalent horizons developed, eg; sulfide-bearing epiclastics, pyritic black shales, limestones? Are the exhalites true seafloor precipitates or simply alteration (silification?) of tuffaceous sediments? Key criteria?

Lau Basin
Yes/visual observation.

Manus Basin
Yes/visual observation.
7.4.2 Are exhalites developed at other stratigraphic levels above or below the ore position? How far above or below?

Lau Basin
No information.

Manus Basin
No information.

7.4.3 Can the exhalites be mapped along strike from the deposit (how far?), and are they useful for exploration? How do you distinguish ore-associated exhalites from barren exhalites?

Lau Basin
Yes, but their areal extent is poorly known.

Manus Basin
Yes, but their areal extent is poorly known.

7.4.4 Is there a geochemical database for exhalites in your belt (how many samples, REE data, isotope data)?

Lau Basin
No.

Manus Basin
No.

7.4.5 List key references

Lau Basin
See topic 3.

Manus Basin
See topic 3.

7.5 Alteration facies

7.5.1 Have hydrothermal, regional diagenetic, and regional metamorphic mineral assemblages and textures been identified? Criteria used for discrimination?

Lau Basin
No.

Manus Basin
No.

7.5.2 What (if any) is the immediate footwall alteration mineralogy and zonation? Is the footwall alteration more commonly in stratabound zones or as pipes? What is the depth extent and surface area relative to the deposit?

Lau Basin
No information.
Manus Basin
No information.

7.5.3 What (if any) is the extent and mineralogy of hangingwall alteration? Give morphology, dimensions and mineral zonation.

Lau Basin
Not applicable.

Manus Basin
Not applicable.

5.4 What particular alteration indices (vectors to ore) have been tested or proposed?

Lau Basin
None.

Manus Basin
None.

5.5 Has a single database of alteration geochemistry been compiled for the district? (number of samples?). By whom? and is it available?

Lau Basin
No.

Manus Basin
No.

7.5.6 Is there a database of whole rock oxygen isotopes? (number of samples?) Is data available on H or C isotopes?

Lau Basin
No database, but few analyses available.

Manus Basin
No.

7.5.7 Have deep semi-conformable alteration zones been identified? What is their dimension, mineralogy, and chemical characteristics? Is there evidence for metal depletion?

Lau Basin
No.

Manus Basin
No.

7.5.8 Is alteration geochemistry used to assist exploration in the district?

Lau Basin
No.

Manus Basin
No.
73.5.9 List key references

Lau Basin
-

Manus Basin
-

7.6 Hydrothermal geochemistry

7.6.1 Are there systematic published studies on the mineralogy, mineral paragenesis and mineral chemistry of the ores and altered host rocks. Which deposits?

Lau Basin
Yes, for Valu Fa Ridge and Northern Lau Basin.

Manus Basin
Yes, for Vienna Woods and Pacmanus. Data on other known deposits has not been published yet.

6.2 Are the temperature, salinity and chemistry of the ore fluid well constrained from deposit data? What is the quality of primary fluid inclusion data?

Lau Basin
Yes, direct fluid sampling at the Valu Fa ridge.

Manus Basin
Yes, direct fluid sampling at the Pacmanus site.

7.6.3 Is there any evidence for fluid boiling, give details?

Lau Basin
Yes, moderate salinity variations in fluid inclusions.

Manus Basin

7.6.4 What hydrothermal thermodynamic modelling has been attempted? What modelling software was used (if any)?

Lau Basin
None.

Manus Basin
None.

7.6.5 What additional information is required to develop robust geochemical models?

Lau Basin
Can be done with available data.

Manus Basin
Can be done with available data.
6.6 List key references

Lau Basin
see topic 3 and additionally:

Manus Basin
see topic 3 and additionally:

7.7 Source of fluids, sulfur and metals

7.7.1 How extensive is the S isotope database on ores, sulfates and host rocks (numbers of analyses)? What is the range of del 34S? Do the massive sulfides and stringer zones have the same mean value and range? What is the interpreted source(s) of sulfur?

Lau Basin

<table>
<thead>
<tr>
<th>Location</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valu Fa ridge</td>
<td>+2.2 – +7.1</td>
</tr>
<tr>
<td>White Church</td>
<td>+6.9 – +16.2</td>
</tr>
<tr>
<td>Vai Lili</td>
<td>-7.7 – -2.8</td>
</tr>
<tr>
<td>Hine Hina</td>
<td></td>
</tr>
<tr>
<td>Northern Lau Basin</td>
<td>+6.1 – +9.8</td>
</tr>
</tbody>
</table>

Source is a combination of leached host rock+seawater+magmatic input (eg Hine Hina).

Manus Basin

<table>
<thead>
<tr>
<th>Location</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vienna Woods</td>
<td>+1.3 – +6.0</td>
</tr>
<tr>
<td>Pacmanus</td>
<td>-1.9 - +2.6</td>
</tr>
</tbody>
</table>

Source is a combination of leached host rock+seawater+magmatic input.

7.7.2 How extensive is the Pb isotope database on ores and host rocks (number of analyses and range of 206/204Pb and 207/204Pb ratios on ores?). What is the interpreted source of metals?

Lau Basin
17 analyses of ores from the Valu Fa Ridge by Fouquet & Marcoux (1995). Data for the Northern Lau Basin is few. 35 analyses of host rocks by various authors. The source of the lead is a variable combination of Pacific and Indian Ocean source with some sediment input (0-3 %). Higher sediment input at Valu Fa Ridge. Central Lau Basin (Northern Lau basin in the paper) is dominated by Indian Ocean source.

Manus Basin
Few data available for ores from the Vienna Woods site. Analyses indicate Indian ocean source.

7.7.3 Is there any other isotopic data (Os/Ir, Sm/Nd, Sr) that may assist in determining
the source of metals?

Lau Basin
Sr-isotopes for few samples in Lescuyer et al. (1993). More extensive data is found in the unpublished thesis by Mühe (1993).
Manus Basin

7.7.4 Is there any evidence for magmatic fluid/metal input? If so what is the key evidence?

Lau Basin
Sulfur isotopes at Hine Hina site.
Manus Basin
Sulfur isotopes at Desmos site—brine-, metal-, and CO₂-rich melt inclusions in host rocks.

7.7.5 What further research is required to determine the source of fluids, sulfur and metals?

Lau Basin
Drilling the interior of the deposits into the stockwork zone.
Manus Basin
Drilling the interior of the deposits into the stockwork zone.

7.7.6 List key references

Lau Basin
See topic 3 and additionally:

Manus Basin
See topic 3 and additionally:

7.8 Subvolcanic intrusions

7.8.1 Have syn-volcanic intrusions been identified and are they associated with VMS
deposits? What is their composition and are they composite?

Lau Basin
A magma chamber has been imaged beneath the Valu Fa Ridge and is believed to be the heat source for the ongoing hydrothermal activity.

Manus Basin
No.

7.8.2 Classify them as shallow (<1000 m from the lowest VMS horizon), epizonal (1000-3000 m) or deep (>3000 m). Is there more than one level present? What is their geometry and dimensions.

Lau Basin
The magma chamber is located 3 km below the seafloor.

Manus Basin
No.

7.8.3 Are they hosted by comagmatic volcanics? Underlying basement?

Lau Basin
A magma chamber has been imaged beneath the Valu Fa Ridge and is believed to be the heat source for the ongoing hydrothermal activity.

Manus Basin
No.

7.8.4 Are they identified as comagmatic to VMS-hosting strata by: a) geology; b) igneous geochemistry, and/or c) geochronology?

Lau Basin
The rift segment itself consists of oceanic crust related to the present magmatic activity, however, previous arc crust might occur in deeper parts of the system.

Manus Basin
No information.

7.8.5 Are they related to district-scale alteration zones? Key evidence?

Lau Basin
No information.

Manus Basin
No information.

7.8.6 Do they contain extensive areas of alteration? Do they contain base-metal and/or gold occurrences?

Lau Basin
No information.

Manus Basin
No information.
7.8.7 List key references

Lau Basin

Manus Basin
-

7.9 Hydrogeological modelling

7.9.1 Are there any published or unpublished hydrogeological models for the district or for individual deposits? What software package was used?

Lau Basin
No.

Manus Basin
No.

7.9.2 Are there any data on the original porosity and permeability of the volcanic and sedimentary facies in the succession?

Lau Basin
ODP drillhole data (logging) is available on regional scale.

Manus Basin
No.

7.9.3 Have regional or local hydrothermal fluid pathways been defined? Using what data or criteria?

Lau Basin
Local pathways are defined through faulting that made parts of the stockwork zone accessible.

Manus Basin
No.

7.9.4 Have any heat sources or fluid driving mechanisms been defined?

Lau Basin
The magma chamber is still present.

Manus Basin
No.

7.9.5 What research is required to develop robust hydrogeological models? What computer codes are suitable and available? What computer code developments are needed to better constrain 3D heat and fluid flow modelling?

Lau Basin
Not applicable.

Manus Basin
Not applicable.
7.9.6 List key references

Lau Basin

Manus Basin
No information.

7.10 Exploration criteria

7.10.1 How where the known deposits found? Provide a list with dates and the key methods. (eg. outcropping gossan, gravity, magnetics, soil geochemistry etc.)

Lau Basin
Water column studies and submersible dive.

Manus Basin
Water column studies and dredging plus submersible dives.

7.10.2 Currently, what are the key methods used by companies to identify 1) prospect areas, and 2) drill targets?

Lau Basin
Not applicable.

Manus Basin
Not applicable.


Lau Basin
Not applicable.

Manus Basin
Not applicable.

7.10.4 What percentage of the volcanic district is under shallow cover? Have any deposits been discovered in the covered areas?

Lau Basin
None.

Manus Basin
None.

7.10.5 What exploration methods need to be considered or further researched in your district?

Lau Basin
Seafloor drilling, small scale geological mapping, and more water column studies.

Manus Basin
Seafloor drilling, small scale geological mapping.

**10.6 List key references**

Lau Basin
None.

Manus Basin
None.

**7.11 Research strengths for your VMS district**

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<th>2</th>
<th>3</th>
<th>4</th>
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<td>2. Volcanic architecture:</td>
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<td>3. Styles of deposits:</td>
<td></td>
<td></td>
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<td>4. Exhalites:</td>
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<td>X</td>
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<td>5. Alteration facies:</td>
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<tr>
<td>6. Hydrothermal geochemistry:</td>
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<tr>
<td>7. Sources of S, metals, fluids:</td>
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<tr>
<td>8. Hydrogeological modelling:</td>
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<tr>
<td>9. Subvolcanic intrusions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

1 = Adequate database and extensive interpretation of data
2 = Adequate database but little interpretation
3 = Extensive interpretation but inadequate database
4 = Moderate database and interpretations (needs improvement)
5 = Inadequate database and little interpretation