Late Neogene History of the Bird's Head Area, West Papua, Indonesia: An Insight From Detrital Zircon*

Indra Gunawan¹, Robert Hall³, and Benyamin Sapiie²

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Abstract

This study presents a review of new results from the Upper Neogene Formation and no research has been carried out concerning its zircon geochronolgy prior to this project. Late Neogene sedimentation in the Bird's Head was characterized by siliciclastic deposition that followed the widespread Early Neogene of the New Guinea Limestone Group. These siliciclastic rocks include the Klasafet, Steenkool, Klasaman Formations, and newly defined Konjah Formation. They are underlain by an extensive carbonate platform, the Kais Formation. In the Bird's Head the important sedimentological change from carbonate to siliciclastic deposition occurred in the Middle to Late Miocene when the Kais Formation was conformably overlain by the Klasafet Formation. For the Phanerozoic zircons, there are three important age group; Pliocene (ca. 3 to 5 Ma), Miocene (ca. 12 to 20 Ma), and Permian–Triassic (ca. 205 to 275 Ma). The most abundant group is Pliocene, found only in the Konjah Formation. In the Precambrian, there are three important group ages. These groups are Neoproterozoic (ca. 0.9 to 1.2 Ga), Mesoproterozoic (ca. 1.4 to 1.6 Ga), and Palaeoproterozoic (ca. 1.8 to 2.0 Ga). There is an increase in the abundance of detrital Precambrian zircons from the Middle Miocene to Lower Pliocene formations. The much larger proportion of Precambrian zircons compared to Phanerozoic zircons in the Klasafet and Steenkool Formations indicates a new older source was available, and the older zircons were not simply derived by reworking of older sedimentary rocks. It is suggested that this increase in abundance of Precambrian zircons marks unroofing of the northeast part of the Bird's Head, the Kemum High, during the deposition of the Upper Neogene siliciclastic rocks. This caused the Silurian–Devonian Kemum Formation and Upper Carboniferous to Triassic
granitic rocks to become available for erosion. There was a second phase of acid igneous activity during the Pliocene in the area which contributed material to the Middle Pliocene Formation. This activity is indicated by Lower to Middle Pliocene zircons found in the Konjah Formation and was never reported previously. All observations support the suggestions there is a Middle Pliocene unconformity in the Bird's Head that continues offshore to the Seram area. This unconformity is probably related to the Sorong Fault movement and predates Seram Trough development. The Konjah Formation was deposited above this unconformity in a fluvial setting.

Selected References


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Talk Outline

- Introduction
- Upper Cenozoic Stratigraphy
- Zircon Geochronology
- Regional Implication
Tectonic setting

- Surrounded by active or recently active zones
- Indian–Australian plate moving NNE
- Pacific Plate moving WNW
- Enigmatic Banda arc
- Cut by Sorong Fault
Bird’s Head Models

(A) Hamilton (1979)

(B) Kroeneke (1984)

(C) Milsom (1985)

(D) Cooper and Taylor (1987)

(E) Dow et al. (1988)

(F) Pilgram et al. (1989)

(G) van Ufford and Cloos (2005)

(H) Hall (2012)

LEGEND

- Subduction zone (>1 to 2 cm/yr) with arc

- Convergence zone (<1 to 2 cm/yr) with no arc

- Inactive subduction zone

Central Range Orogeny

Peninsular Orogeny

N

0 Km 1000
Bird’s Head Models

- Favoured of an active margin setting
Agree that the passive margin is in the Bird’s Head that lead to the development of the New Guinea Lst. Group.
Bird’s Head Models

• Agree that the passive margin is in the Bird’s Head that lead to the development of the New Guinea Lst. Group.

No Zr geochronology study prior to this project
Late Cenozoic Stratigraphy

- Miocene – Pleistocene siliciclastic sequence
- Miocene collision
- Extensive Miocene carbonate platform

**Simplified chronostratigraphic diagram of the Bird’s Head area based on field observation**
Upper Neogene Rocks Distribution

- Konjah Formation (Upper Pliocene–Pleistocene)
- Klasaman Formation (Lower Pliocene)
- Steenkool Formation (Lower Pliocene)
- Klasafet Formation (Middle–Late Miocene)
Klasafet Formation (east)

(A) Interbedded mudstones and sandstones of the Klasafet Formation at PR 32 show load structures. (B) Grey and poorly bedded calcarenite at PR 31. (C) Bedding parallel burrows within the calcarenite. (D) Well-bedded mudstone and calcareous sandstone with carbonate intercalations at PR 29. (E) Calciturbidite outcrop at PR 29. (F) The contact between the calcareous Klasafet Formation and the non-calcareous Steenkool Formation at PR 28. (G) The erosional surface between the Klasafet and Steenkool Formations at PR 28.

- characterised by interbedded sandstone and mudstone with locally intercalations of limestone.
Klasafet Formation (west)

- characterised by thick calcareous mudstone with locally intercalations of sandstone and limestone).
- shallow marine environment

(A) Massive calcareous sandstone on top of finely laminated mudstone outcrop at PSIG 04 in the lower section of the Klasafet Formation.

(B) Thick calcareous mudstone outcrop at PS 36 shows slump structures in the calcareous sandstone unit.

(C) Thick calcareous mudstone and sandstone intercalations outcrop at PS 36 dips gently to the southeast with mudstone unit thicknesses that can reach up to five metres.

(D) Well bedded mudstone and sandstone outcrop of the Klasafet Formation at PS 36 in the Klamono area dips gently to the southwest.

(E) The sandstone is grey, rich in mollusc and foraminifera fossils, well compacted, and consists of well sorted fine- to medium-grained sand.
The Steenkool Formation consists of interbedded carbonaceous siltstone and mudstone. It is found in a shallow marine to deltaic environment.
Klasaman Formation and Sele Conglomerate

Unconformity c=J Conglomerate

Mudstone -------- Erosional

Cross planar bedding

Horizontal planar lamination

Diagram showing layers and bedding planes.
The Klasaman Formation is characterised by finely laminated calcareous Mudstone.
The Konjah Formation is newly defined and it was previously mapped as Sirga Formation by previous authors. It is characterised by loose quartz rich sandstone and a Middle Pliocene unconformity.
The Konjah Formation is newly defined and it was previously mapped as Sirga Formation by previous authors. It is characterised by loose quartz rich sandstone. A Middle Pliocene unconformity is associated with the Konjah Formation.
The Konjah Formation is newly defined and it was previously mapped as Sirga Formation by previous authors.

- characterised by loose quartz rich sandstone
- Middle Pliocene unconformity
The depositional age of the Kais, Klasafet, Steenkool, and Klasaman Formations

- Klamono
  - Klasafet Fm. Klasaman Fm.
  - IG10-PS67
  - IG10-PS69
- Ayamaru
  - Kais Fm.
  - IG0-PS9
  - IG0-PS9
- Bintuni
  - Klasafet Fm.
  - IG10-PR38
  - IG10-PR43

**Upper Neogene Biostratigraphy**
The depositional age of the Kais, Klasafet, Steenkool, and Klasaman Formations

- The Klasafet Fm was deposited in shallow inner neritic environment during the Late Middle Miocene (Serravallian) to Late Miocene (Messinian).
- The lower part of the Klasafet Fm was deposited contemporaneous with the Kais Fm.
- The Steenkool and Klasaman Fms. has a narrow age bracket of Early Pliocene (Zanclean) and were deposited in shallow marine environment.

Upper Neogene Biostratigraphy
Upper Neogene Rocks Heavy Mineral Characteristics
Upper Neogene Rocks Heavy Mineral Characteristics

- In summary, the heavy minerals of the Late Neogene siliciclastic samples characterised by granitic and older sedimentary source rocks.
- The heavy minerals of the Klasafet Fm. were also derived from low-grade metamorphic rocks and Steenkool and Konjah Formations were sourced from, basic to intermediate igneous rocks.
- No known arc-continental collision association

<table>
<thead>
<tr>
<th>Formation</th>
<th>%HM</th>
<th>Zircon</th>
<th>Muscovite</th>
<th>Opaque (hematite)</th>
<th>Garnet</th>
<th>Tourmaline</th>
<th>Chlorite</th>
<th>Rutile</th>
<th>Topaz</th>
<th>Hypersthene</th>
<th>Sphene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klasafet</td>
<td>1.13</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>XXX</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Steenkool</td>
<td>0.46</td>
<td>XX</td>
<td>O</td>
<td>XX</td>
<td>O</td>
<td>O</td>
<td>–</td>
<td>O</td>
<td>O</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Konjah</td>
<td>1.21</td>
<td>XXX</td>
<td>X</td>
<td>XX</td>
<td>X</td>
<td>XX</td>
<td>–</td>
<td>X</td>
<td>XX</td>
<td>O</td>
<td>–</td>
</tr>
<tr>
<td>Konjah</td>
<td>2.72</td>
<td>XXX</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>–</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>Konjah</td>
<td>9.58</td>
<td>XXX</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>–</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
</tbody>
</table>

**Explanation:**
- O Traces
- X Low abundance
- XX Moderate abundance
- XXX High abundance
- – Not present
Zircon Geochronology

- Represents Middle Miocene and Permian–Triassic grains
- Scattered Precambrian zircon grains
- Represents Middle Miocene and Permian–Triassic grains
- Paleoproterozoic zircon grains (~1.8 Ga), much larger proportion of Precambrian zircons
Zircon Geochronology

- Represents Middle Miocene and Permian–Triassic grains
- Paleoproterozoic zircon grains (~1.8 Ga), much larger proportion of Precambrian zircons
Zircon Geochronology

Konjah Formation

Analyses number

Probability

Age, Ma

Proterozoic

Archean

n = 117

n = 22

Cen K J T P C D S' O
• Represents Middle Miocene and Permian–Triassic grains
- Represents Middle Miocene and Permian–Triassic grains
- Mesoproterozoic - Paleoproterozoic zircon grains
Zircon Geochronology

- Represents Middle Miocene and Permian–Triassic grains
- Mesoproterozoic - Paleoproterozoic zircon grains
- Abundant Pliocene zircons with Archaean grain therefore not Oligocene Sirga Formation
Possible Sources Area

- **Group A**: 0.9-1.2 Ga
- **Group B**: 1.2-2.0 Ga
- **Group C**: ca. 205-215 Ma
- **Group D**: ca. 1.4-1.6 Ga
- **Group E**: ca. 1.4-1.6 Ga
- **Group F**: ca. 1.4-1.6 Ga
- **Group G**: ca. 12-20 Ma
- **Group H**: ca. 5-10 Ma

**Analyses number**

- **Pi**: 30-40
- **Mio**: 30-40
- **Oli**: 30-40
- **Eoc**: 30-40
- **Pal**: 30-40

**Age, Ma**

- **Cen**: 0-70
- **K**: 0-70
- **J**: 0-70
- **T**: 0-70
- **P**: 0-70
- **C**: 0-70
- **D**: 0-70
- **S1**: 0-70
- **O**: 0-70

**Probability**

- **Group A**: 0.001-0.6
- **Group B**: 0.001-0.6
- **Group C**: 0.001-0.6
- **Group D**: 0.001-0.6
- **Group E**: 0.001-0.6
- **Group F**: 0.001-0.6
- **Group G**: 0.001-0.6
- **Group H**: 0.001-0.6

**Archean**

- **n**: 66
Pliocene zircons (Group A, around 3–5 Ma) are only found in the Pleistocene Konjah Formation.
Pliocene zircons (Group A, around 3–5 Ma) are only found in the Pleistocene Konjah Formation.

Little information of Pliocene age igneous rocks in the BH’s.

Matched with nearby dacite intrusions dated at around 3.5 Ma and cut the Middle Miocene Kais Formation.

Another possibility were related to the Sorong Fault movement that was initiated in the Early Miocene and last until the Pliocene (Hall, 2002; Hall, 2011, 2012).
<table>
<thead>
<tr>
<th>Age (Period)</th>
<th>Unit</th>
<th>Distribution</th>
<th>K/Ar Age (Ma)</th>
<th>Minerals</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>(?) Middle Miocene</td>
<td>Lembai Diorite</td>
<td>NNE Bird's Head</td>
<td>15</td>
<td>Hornblende</td>
<td>Robinson and Ratman (1978); Bladon (1988); Pieters et al. (1990); Robinson et al. (1990)</td>
</tr>
<tr>
<td>Late Cretaceous; Middle–Late Triassic</td>
<td>Sorong Granite</td>
<td>NW Coast of Bird's Head, K-1X well in Salawati area</td>
<td>70–72; 224–235</td>
<td>Biotite and Amphibole</td>
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</tr>
<tr>
<td>Triassic</td>
<td>Netoni Intrusive Complex</td>
<td>N of Sorong Fault, NE Bird's Head</td>
<td>198–241</td>
<td>Biotite and Hornblende</td>
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<td>E Bird's Head, NW Ranski Fault</td>
<td>227–295</td>
<td>Muscovite and Biotite</td>
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<tr>
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<td>Wariki Granodiorite</td>
<td>NE Bird's Head</td>
<td>226–258</td>
<td>Biotite</td>
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<tr>
<td>Late Carboniferous–Early Permian</td>
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<td>Central of E Bird's Head</td>
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<td>Melaiurna Granite</td>
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**Possible Sources Area**
Miocene zircons (Group B, around 12–20 Ma) and can be matched with the Lembai Diorite.
### Possible Sources Area

#### Age (Period)  
#### Unit  
#### Distribution  
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#### Sources

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- Miocene zircons (Group B, around 12–20 Ma) and can be matched with the Lembai Diorite
- Important group of Permian–Triassic ages (Group C, around 205–275 Ma) can be matched with those of nearby intrusive bodies outcropping to the northeast of the Ayamaru area.
The Permian–Triassic and Proterozoic (Group D (around 0.9–1.2 Ga), Group E (around 1.4–1.6 Ga), and Group F (around 1.8–2.0 Ga)) zircons from the Late Neogene sequence could be reworked from older sedimentary rocks.
So Far.....

- Prior to Middle Miocene the BH’s was on Passive Margin
- Important sedimentological changes occurred in the Bird’s Head in the Middle-Late Miocene
- Then the transform margin developed to the north of BH’s area

*With a little bit ingredient of Zircon*

- Middle Miocene and Pliocene acid igneous activity
- Much larger proportion of Precambrian zircons indicates a new older source was available
- The Middle Pliocene unconformity in the Bird’s Head
Regional Implication

• There was acid igneous activity during the Middle Miocene

• A new older source was available, and the older zircons were not simply derived by reworking of older sedimentary rocks.

• Unroofing of the northeast part of the Bird's Head, the Kemum High
Regional Implication

- Siliciclastic deposition continued
- Second phase of acid igneous activity during the Pliocene in the Bird’s Head
- The Middle Pliocene unconformity and supports the seismic interpretation of a Pliocene unconformity in the Seram area that was suggested by Pairault et al. (2003)
- This major unconformity is probably related to the Sorong Fault movement
Terimakasih

Thank You