AusIMM Branch | New Zealand

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Natural Decay of ANFO-Derived Nitrate in Pit Lakes:

Insights from the Golden Bar Pit Lake, Macraes Gold Mine, Otago, New Zealand

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PRESENTATION OUTLINE

- Background: What is denitrification and nitrification
- Study location
- Water balance, nitrogen concentrations, and loads in the pit lake
- Modelling and initial nitrogen load estimations
- Key messages and takeaways

BACKGROUND

- Blasting residues from ANFO (Ammonium Nitrate Fuel Oil) can release nitrogenous compounds:

$$ANFO\ (NH_4\ NO_3\ ) \rightarrow\ NH_4^+ + NO_3^- \qquad \text{Eqn 1.}$$

- Nitrification (ammoniacal nitrogen converts to nitrate)

$$NH_4^+ + O^2\ \rightarrow\ NO_2^- + H_2O \qquad \text{Eqn 2.}$$

$$2NH_3 + 3O^2 = 2NO_2^- + 2H_2O \qquad \text{Eqn 3.}$$

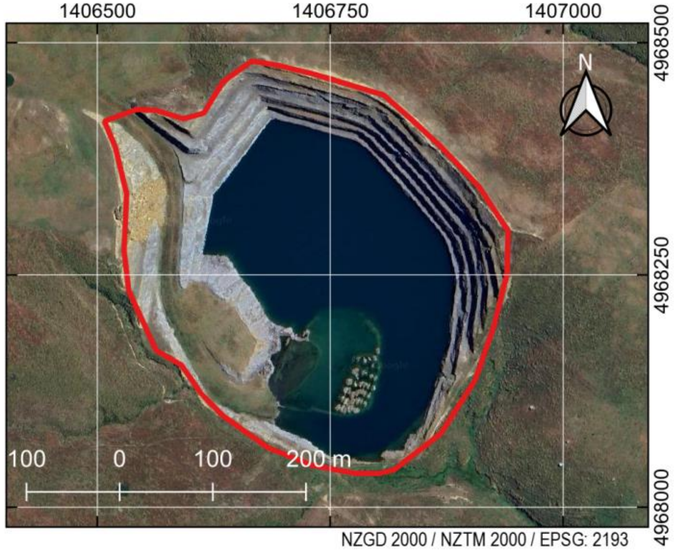
$$NO_2^- + H_2O = NO_3^- + 2H^+ + 2e^- \qquad \text{Eqn 4.}$$

- Denitrification (Nitrate converts to nitrogen gas)

$$2NO_3^- + 12H^+ + 10e^- = N_2 + 6H_2O \qquad \text{Eqn 5.}$$

STUDY LOCATION

- Golden Bar Pit Lake, Macraes Mine, Otago
- Pit lake began filling in 2005
- Neutral to alkaline pH and sulfate <280 mg/L
- Plan area of 131,000 m^2



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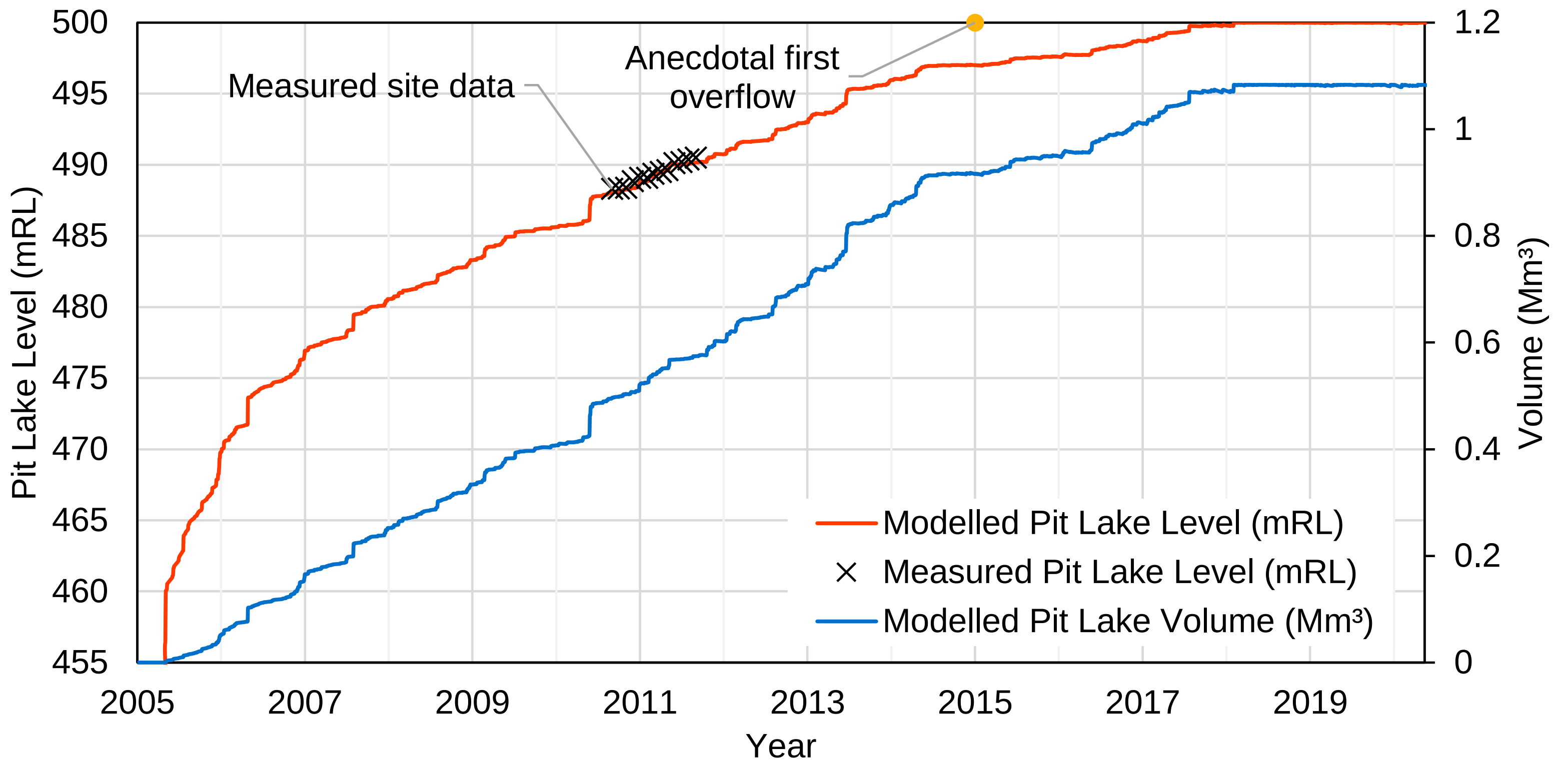
RESULTS: WATER BALANCE

- Water quality data at monitoring location below the GPL discharge point suggest pit lake spilling or seepage from the lake could have occurred from 2015 onwards.
- Model results provide a consistent discharge from 2018 onwards.



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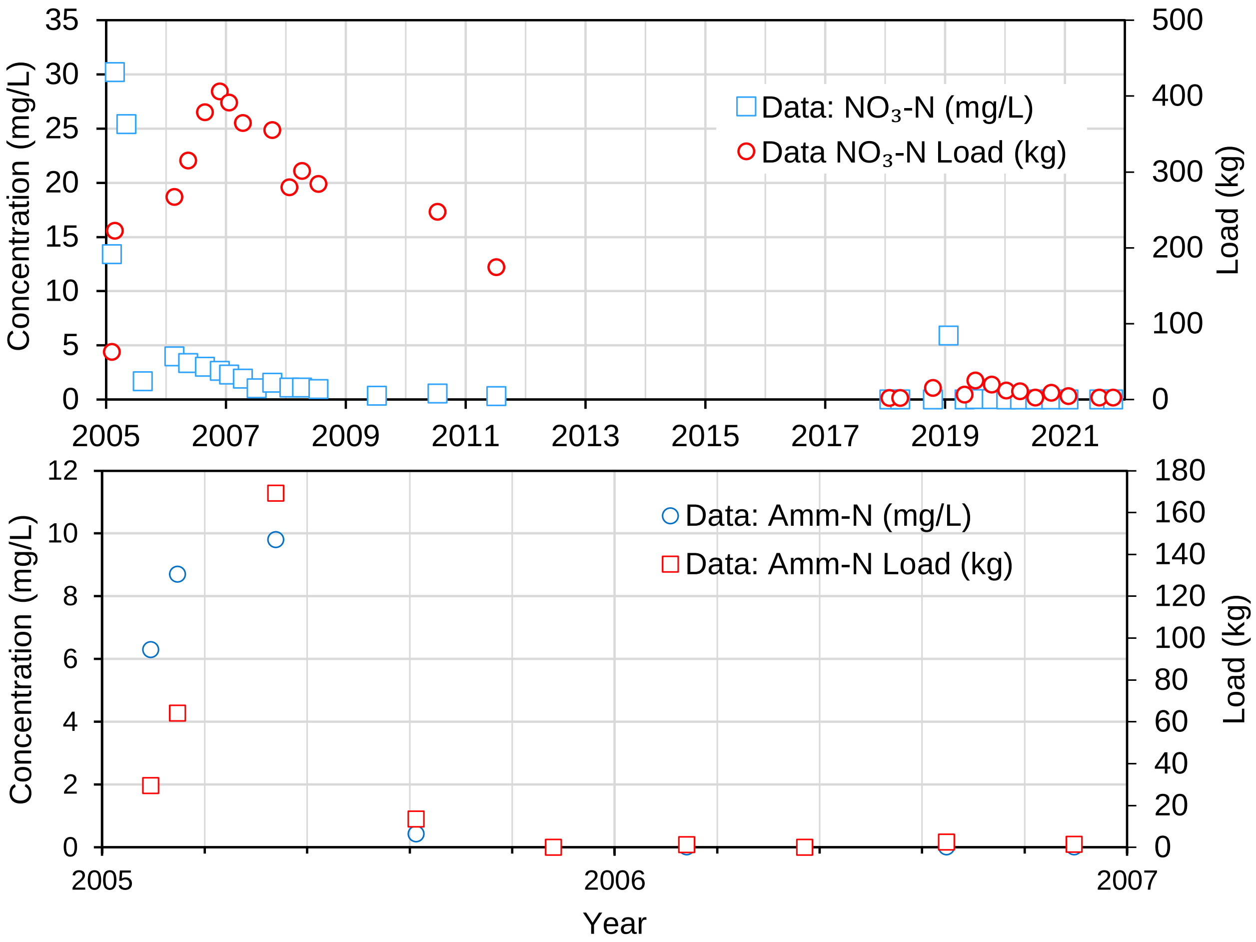
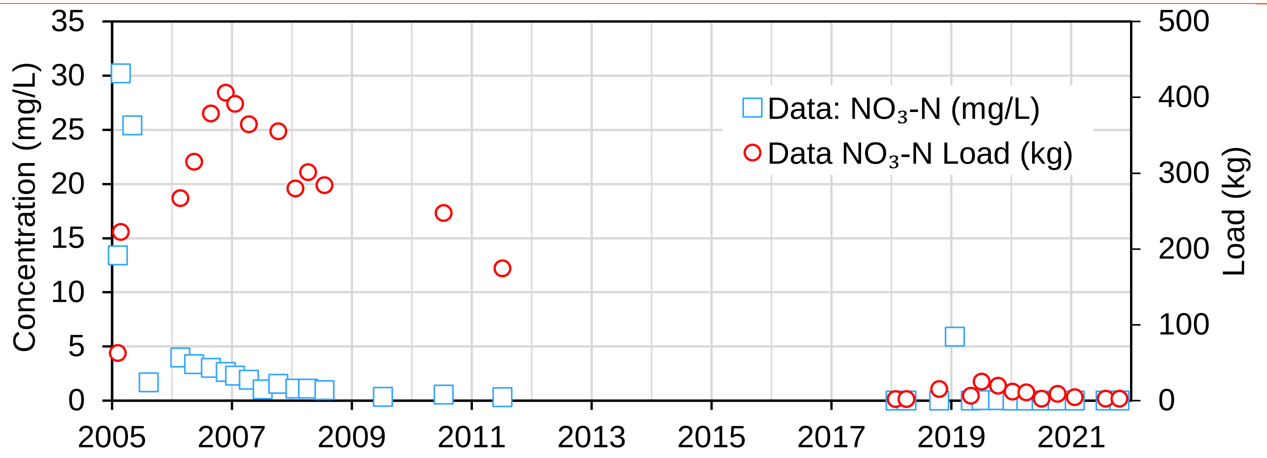
RESULTS: Nitrogen Concentrations and Loads

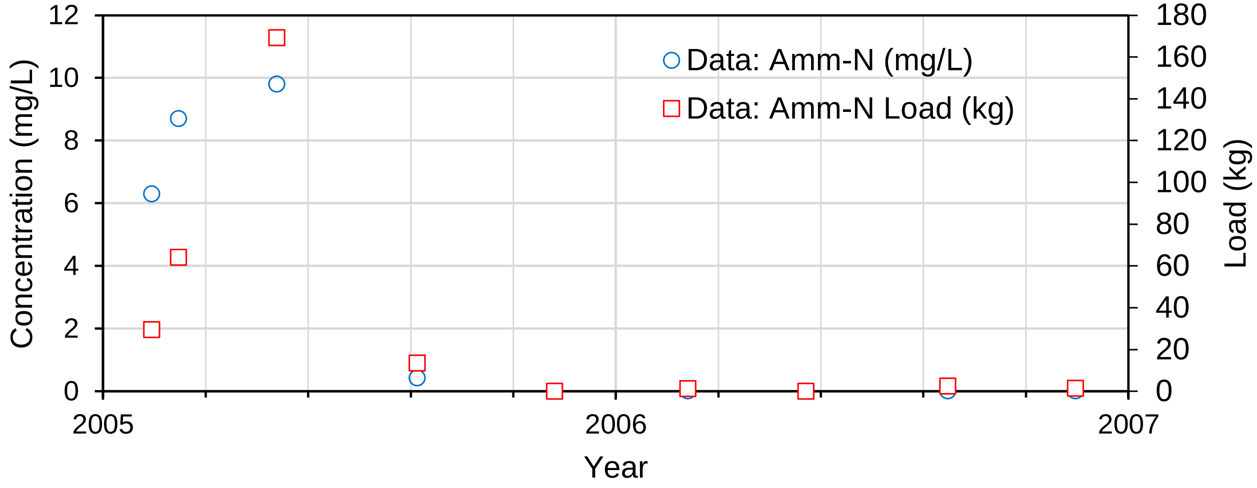
- Nitrate-N
  - 2005: Concentration peaks at 30 mg/L
  - 2007: Load peaks at ~400 kg
  - 2018: Load ~ 0 kg
- Amm-N:
  - 2005: Concentration peaks at ~10 mg/L
  - 2005: Load peaks at ~170 kg
  - 2006: Load and concentration ~ 0



RESULTS: Nitrogen Concentrations and Loads

- Nitrogen was not a conservative contaminant and is removed from solution (i.e., the pit lake), as evidenced by the decrease in load prior to the lake overtopping.
- Nitrate load in the pit lake decreases relatively quickly (e.g., 20-30% per year).





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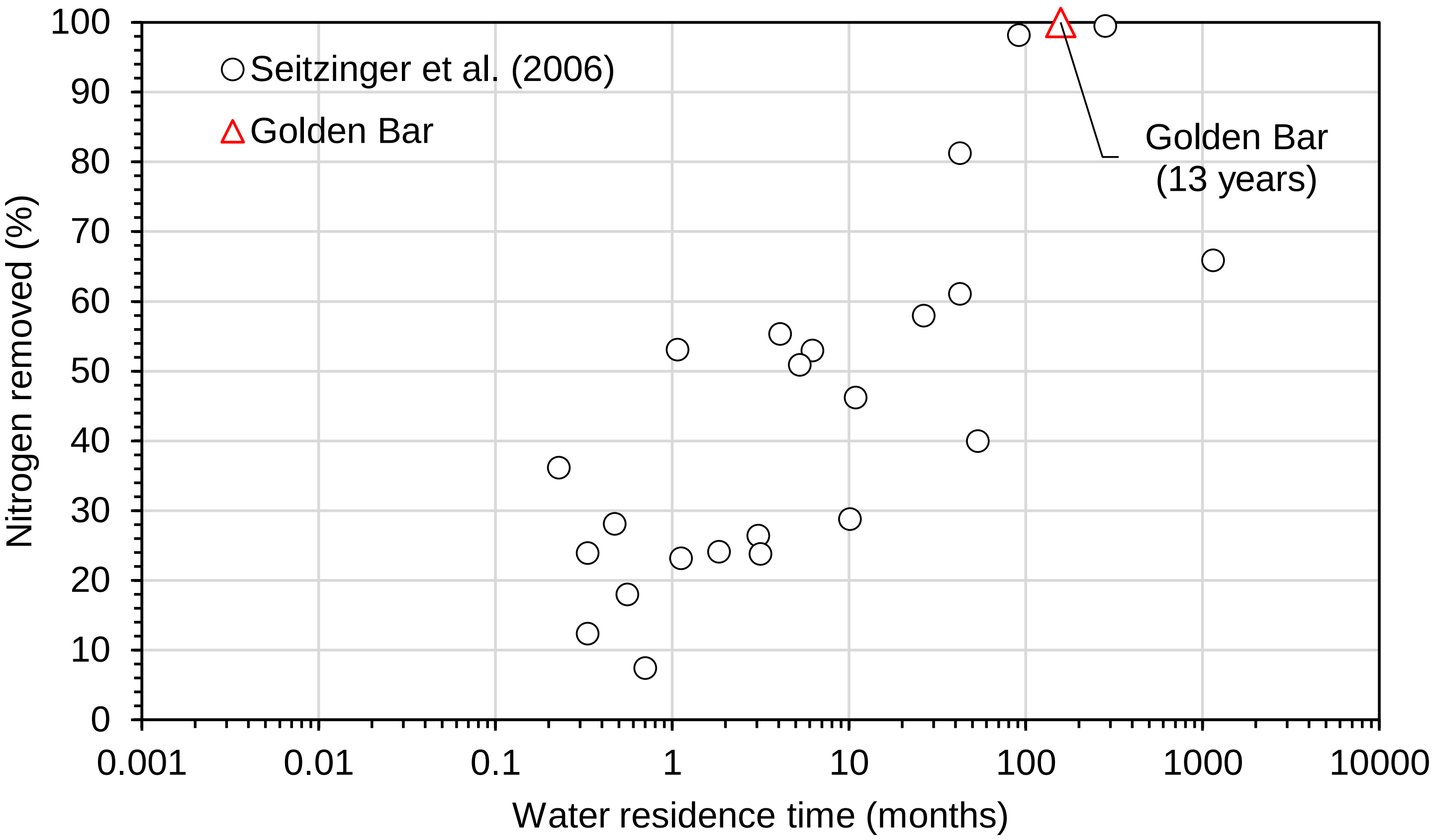
RESULTS: Nitrogen Concentrations and Loads

- Water residency has been recognized as a critical factor controlling the proportion of denitrified N inputs (Seitzinger et al., 2006).
- This finding highlights the significance of considering water residence time as a key factor in managing and predicting nitrogen dynamics within the pit lakes.



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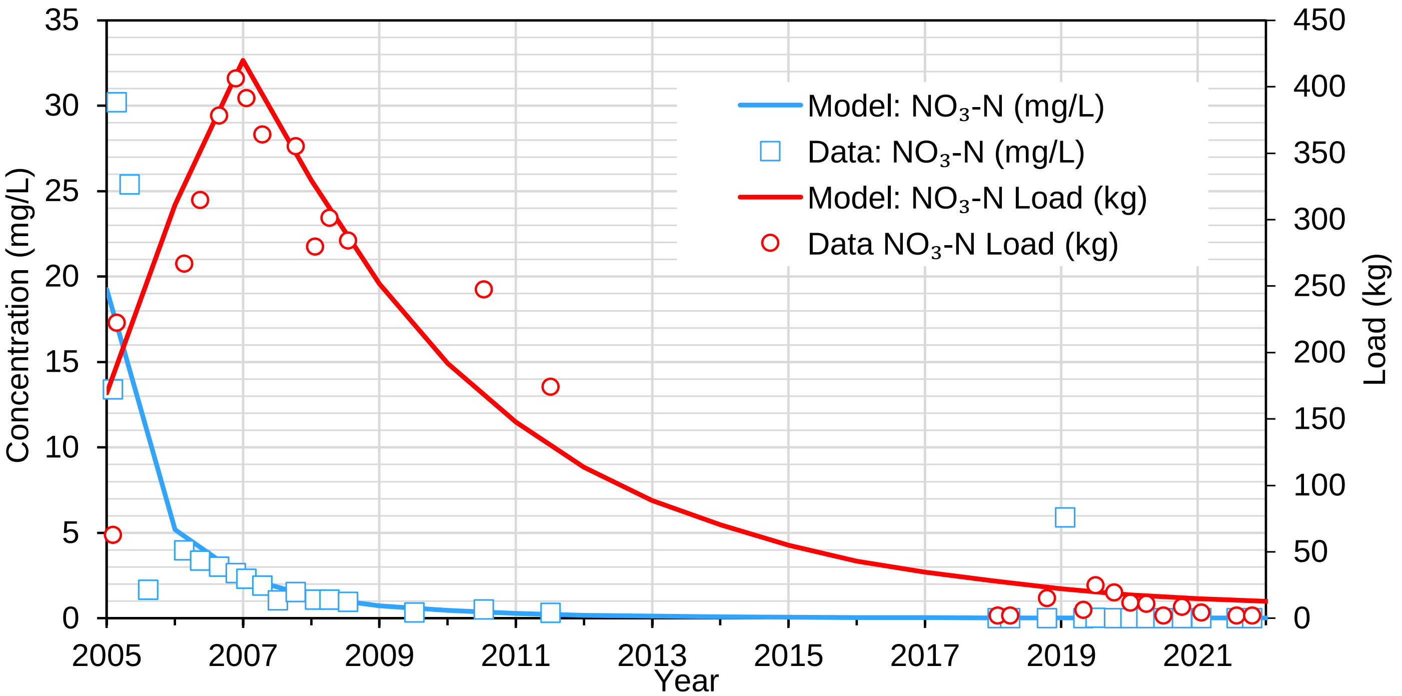
Model: Nitrogen Concentrations and Loads

- A water quality model using PHREEQC was developed
- 2 kinetic processes included: nitrification and denitrification.
- Calibration: 700 kg of Nitrogen (as NH_4NO_3) released in 2005-2007
  - $AmmH^+ = Amm + H^+$
  - $NO_3^- + 2H^+ + 2e^- = NO_2^- + H_2O$
  - $2\,NO_3^- + 12\,H^+ + 10\,e^- = N^2 + 6\,H_2O$
- 700 kg in a plan area of 131,000 m² = 5,35 g/m²



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KEY MESSAGES

- This study provides evidence of how nitrogenous compounds decrease with time within a pit lake environment.
- The results suggest that potentially, the process could be used to design a pit lake treatment system for nitrogenous compounds.
- With proper monitoring, a pit lake nitrate treatment reactor could become an eco-friendly and sustainable solution for mitigating nitrate pollution in mining-affected water bodies.

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KEY TAKEAWAYS

- ANFO blasting residues have resulted in **high initial concentrations of nitrate** (NO_3 - N) in the pit lake.
- Nitrification led to an **initial increase in nitrate concentrations**, while denitrification facilitated the reduction of nitrate loads, especially after reaching the peak in 2007.
- **Nitrogen is not a conservative contaminant** and is subject to natural removal processes over time (20-30% per year).
- ***Ammoniacal nitrogen*** also exhibited a rapid decay, primarily **attributed to nitrification**. This study highlights the importance of considering biochemical processes in pit lake water quality assessments and management strategies.
- The required amount of nitrogen (in the form of **ammonium nitrate**) was determined to be approximately **5.35 grams per square meter of the plan area of the pit.**




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