Sequential Decision-Support for Optimal Exploration Planning

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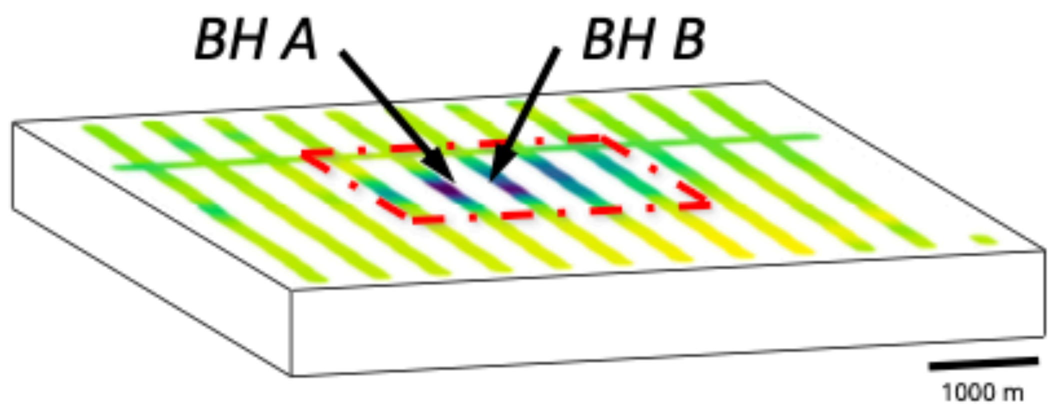
Problem: Collect Geophysics or Go Drill?



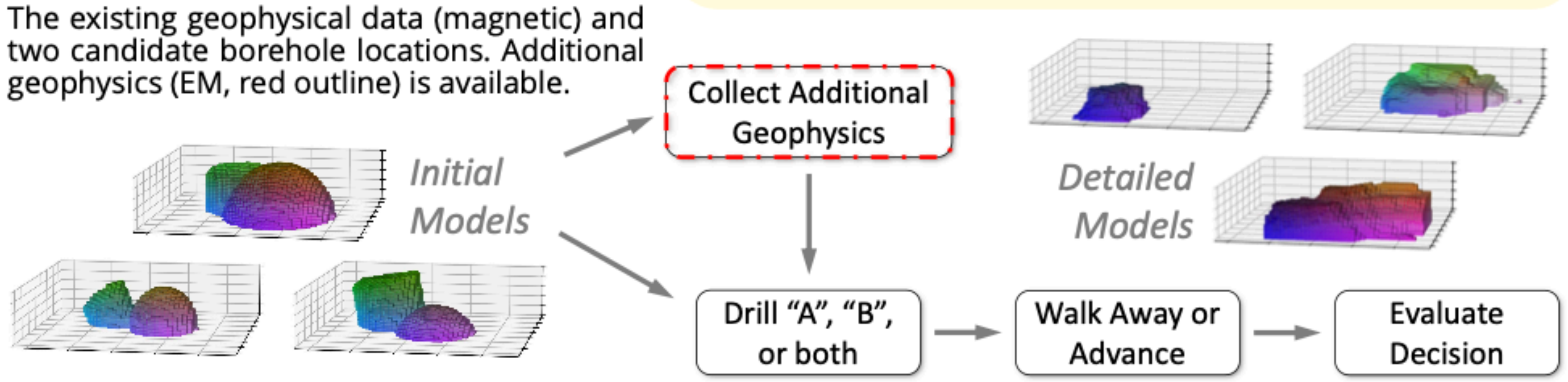
Perform geophysics and then drill two boreholes?

Go straight to drilling?

Which borehole should be drilled first?

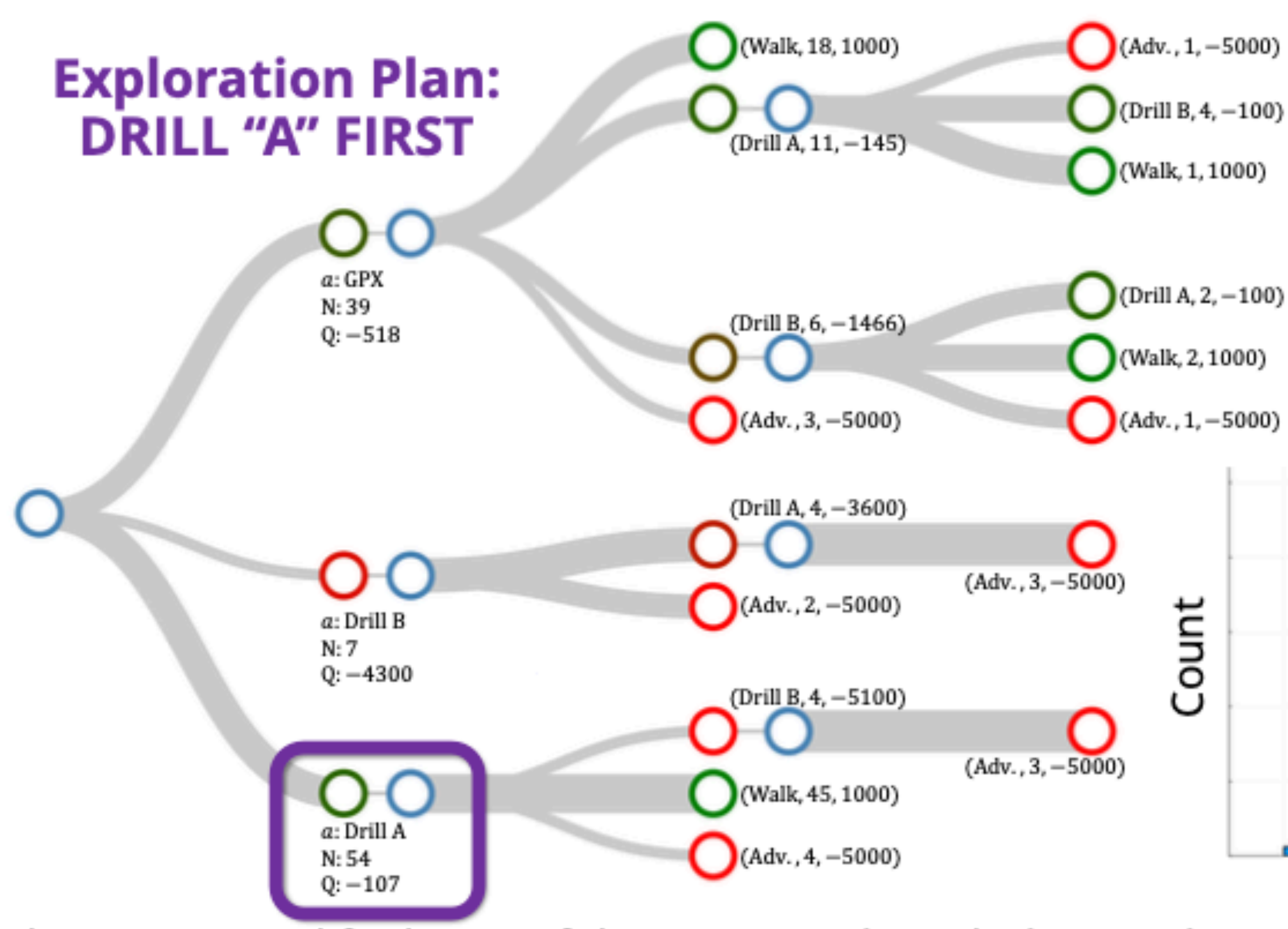
When do we walk away?

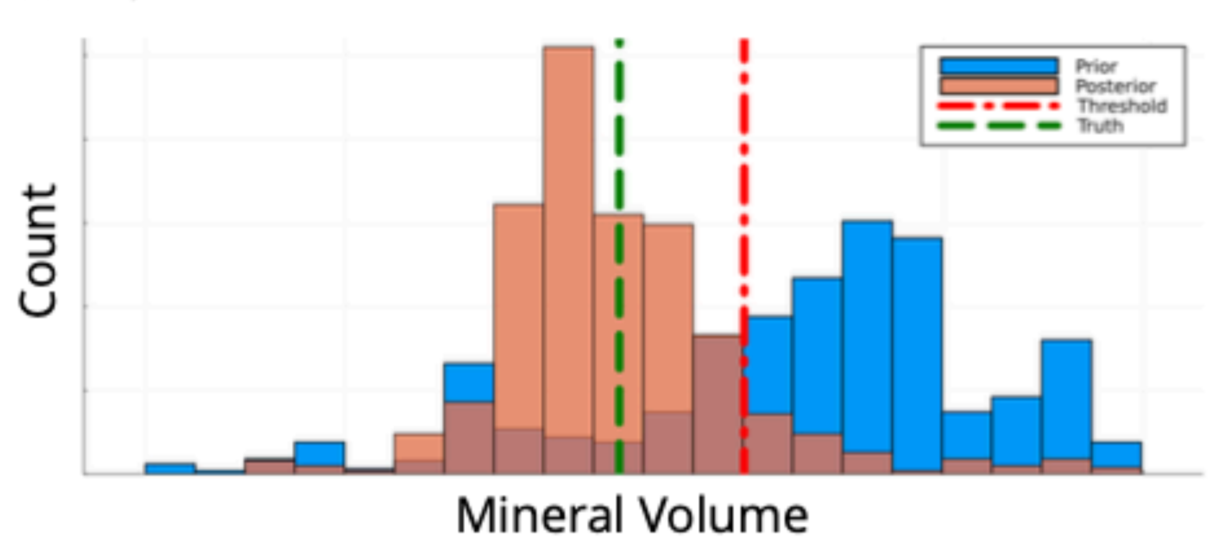
The existing geophysical data (magnetic) and two candidate borehole locations. Additional geophysics (EM, red outline) is available.



A flowchart which shows how a decision-maker can either choose to plan exploration drilling using the "Initial Models", or using a suite of "Detailed Models" after performing geophysics. The decision-maker then chooses to either Walk Away from the prospect, or Advance it for further study.

Solution: Monte Carlo Tree Search





Above is a simplified view of the tree search, with the Q-Value assigned to each action (green/red) and number of visits to each node. A single belief node, in blue, is shown after each step. The histogram (above) shows an example of the distribution of mineral volume **before** and **after** drilling one borehole. The reward of Walk Away or Advance is assigned based on whether the **true volume** exceeds a **pre-determined threshold**, depending on the decision-maker's preference.

Acknowledgements

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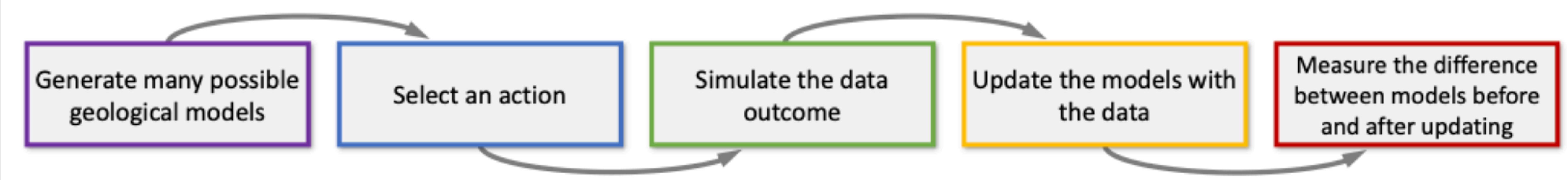
Summary and Main Takeaways

- We present a case where a decision-maker wants to know: should they collect additional geophysics prior to conducting a drilling campaign?
- To address this general problem, we mathematically formulate mineral exploration as a belief-state Markov decision process and solve it using Monte Carlo tree search.
- We show **in this example, the decision-maker should skip straight to drilling.**
- Future work includes a sensitivity study in order to account for computational complexity and show under what scenarios the decision-maker modifies their plan.

Methodology: Building the Framework

A belief-state Markov decision process (MDP) is a formulation of a decision-making problem which incorporates the five elements below. Using this formulation means the belief-state MDP can be solved. To solve the belief-state MDP and therefore output the optimal plan, an algorithm (Monte Carlo Tree Search, left panel) searches over all possible states, actions, and observations.



State: Ensemble of 1000 possible geological models

Observations: Borehole logging data, given all possible geological models

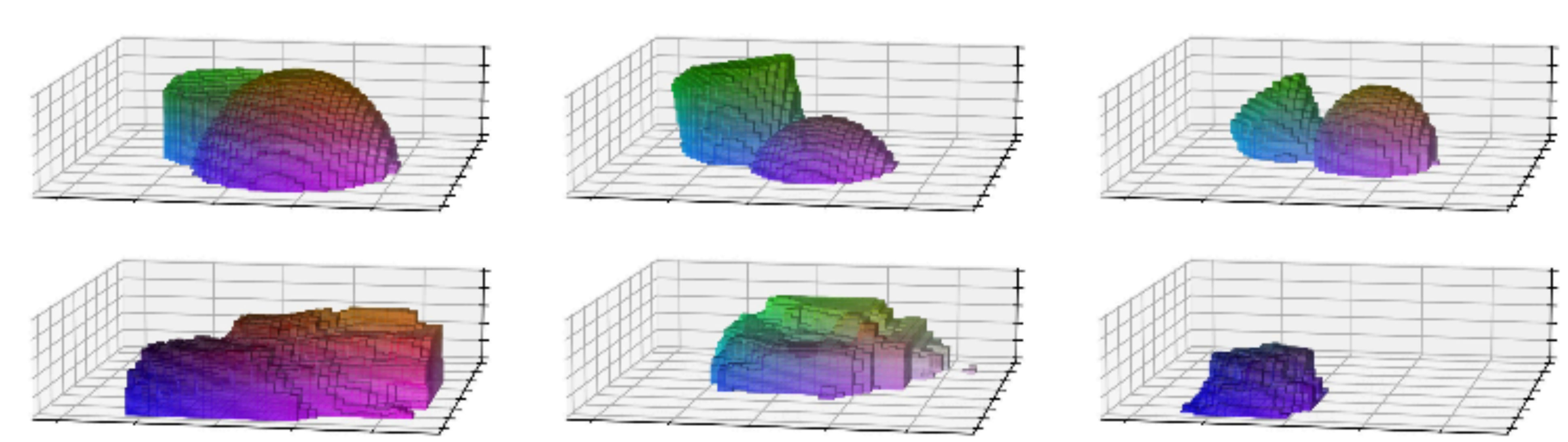
Actions: Drilling, collecting geophysics, walking away, or advancing for more detailed study

Belief Update: Ensemble Smoother

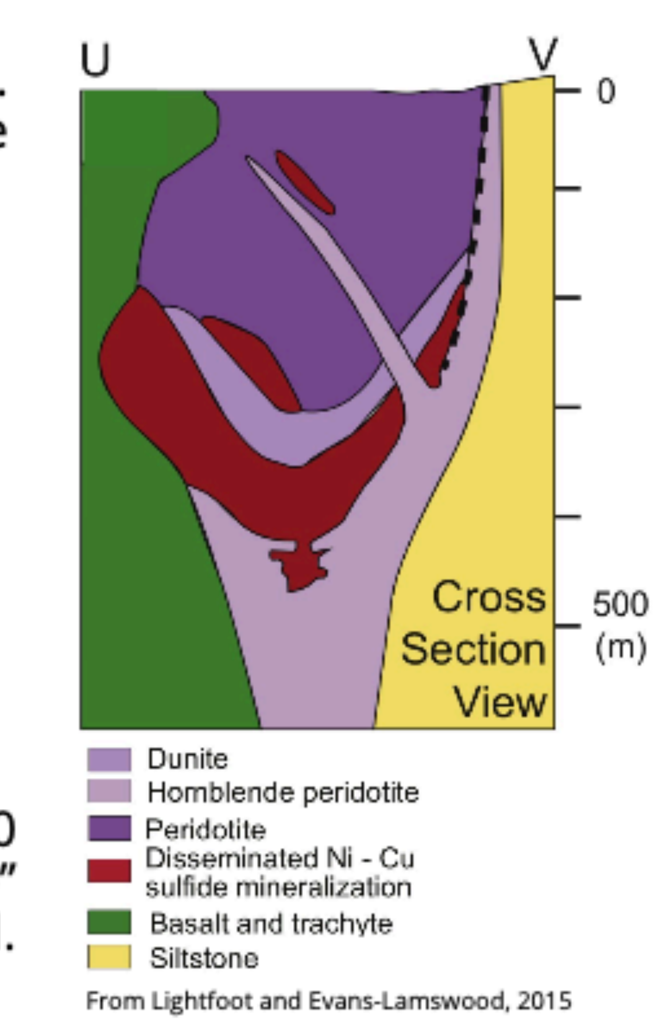
Reward: Correct advance or walk away final decision, proportion of anomaly intersected

Geological Modelling

We developed this case using real data from a prospective area in Western Australia. Western Australia is known for hosting several high-grade Ni-Cu-PGE deposits. The geometry of the intrusion studied is similar to the Huangshan intrusion (right).



Model Realizations: Geological models are uncertain; we use an ensemble of 1000 geological models in order to account for this uncertainty. Top row: "simple" geophysical inversions. Bottom: Geophysical inversions using sketch-based method. Depth of each grid is 500 meters. Top of intrusion is shown. Color indicates position.



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