Tectonic Environments of Cobalt in South America revealed through Support Vector Machines and Random Forests

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LITERATURE REVIEW

DEPOSIT TYPE:

- Sediment hosted
- Laterites
- Magmatic sulphides
- Hydrothermal and volcanogenic
- Manganese nodules and cobalt-rich crusts

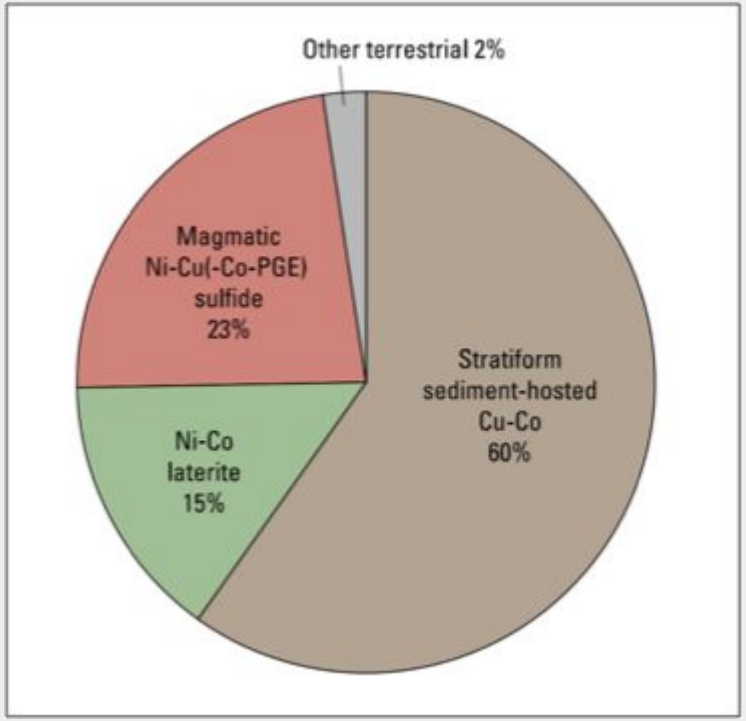


Figure 1. Pie chart showing the percentage of world cobalt mine production by deposit type. Source: *Slack et al. (2017)*

LOCATION REVIEW

TWO MAJOR LANDFORMS:

- Eastern margin
  - The Andes
  - Subduction zone
  - Volcanic activity
- Western margin
  - Cratons
  - Sedimentary basins

MINERAL REVIEW

MACHINE LEARNING REVIEW

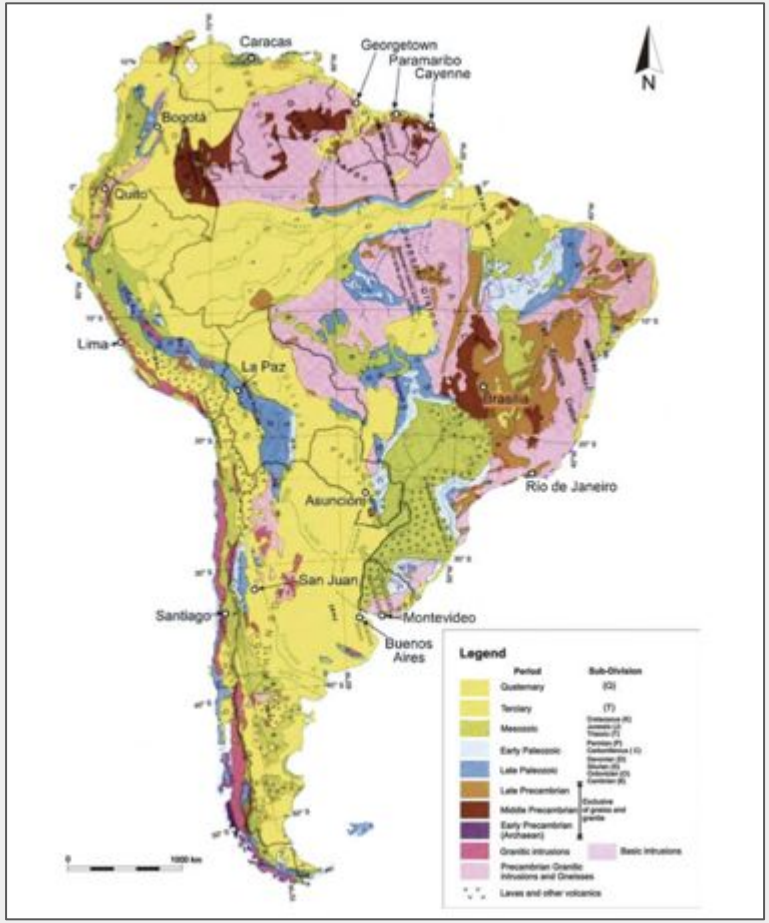


Figure 2. Geological map of South America. Source: *Acevedo et al. (2015)*

DATA SET

Age of Cobalt Deposits

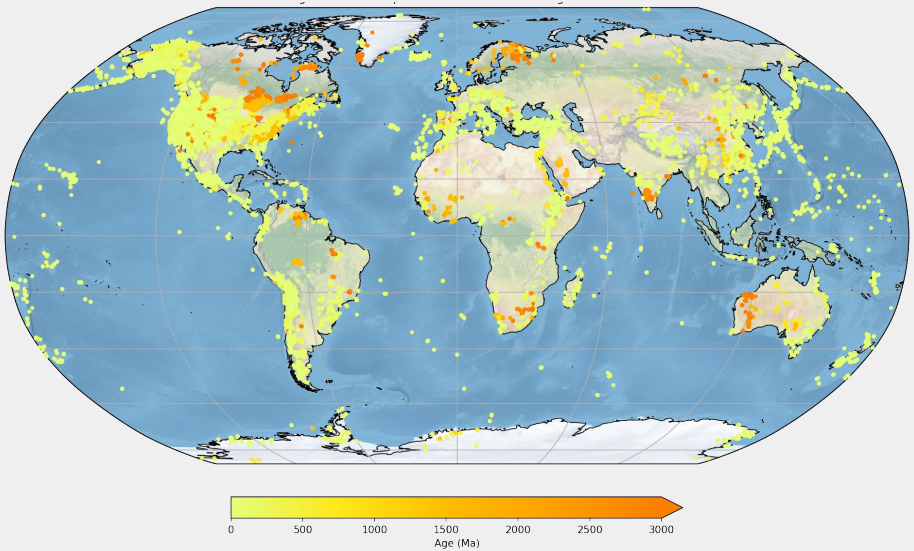


Figure 3. Map of cobalt deposit data from *EarthChem.org* database, coloured by age of the deposit. Created with python, utilising *matplotlib* and *cartopy* python open source libraries.

Concentration of Cobalt Deposits

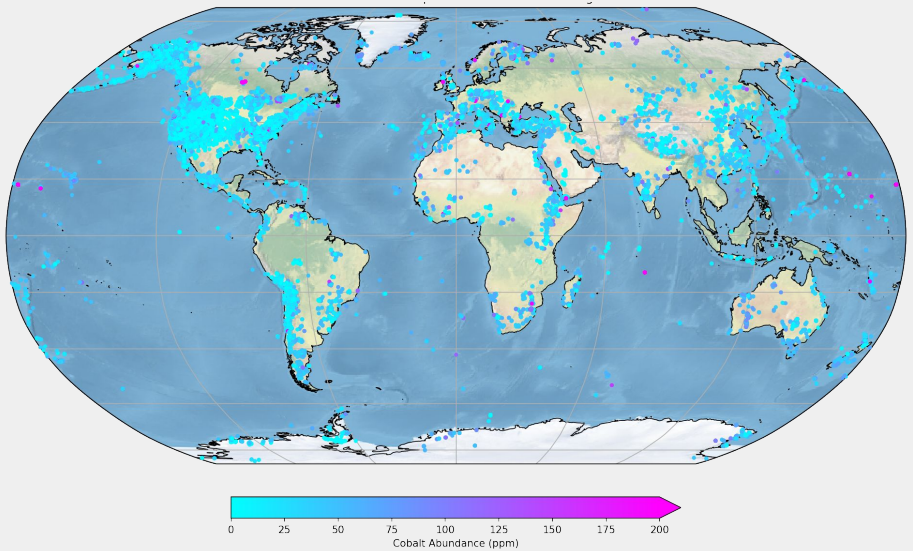


Figure 4. Map of cobalt deposit data from *EarthChem.org* database, coloured by abundance of cobalt in the deposit. Created with python, utilising *matplotlib* and *cartopy* python open source libraries.

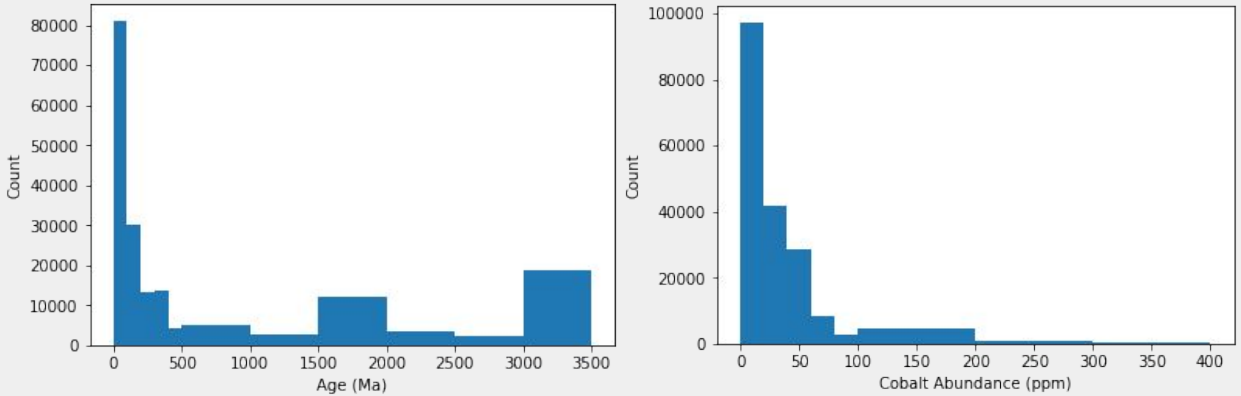


Figure 5. Histogram of worldwide cobalt data from *EarthChem* database. Left: Age of cobalt deposits. Right: Concentration of cobalt within the deposits

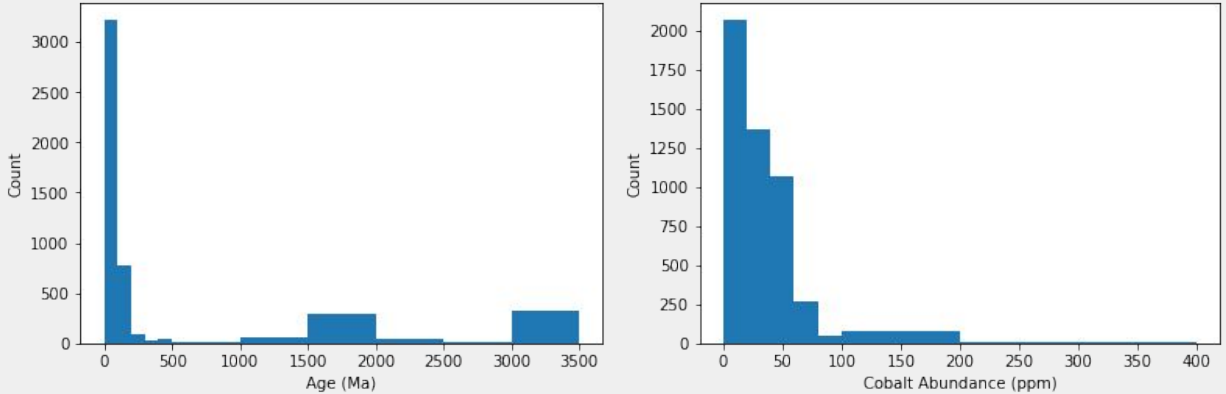


Figure 6. Histogram of worldwide cobalt data from *EarthChem* database. Left: Age of cobalt deposits. Right: Concentration of cobalt within the deposits

METHODS

PLATE RECONSTRUCTION

DATA ANALYSIS

MACHINE LEARNING

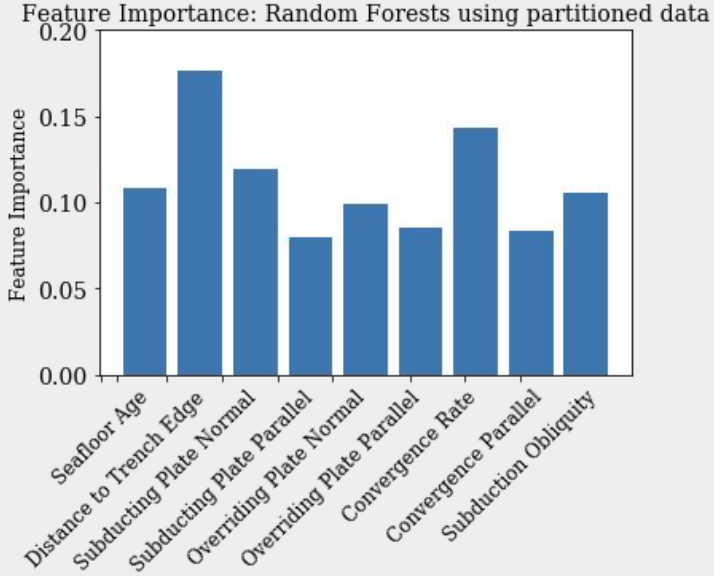


Figure 7. Histogram of displaying the most important features of the subduction zone to cobalt deposit formation, according to Random Forests

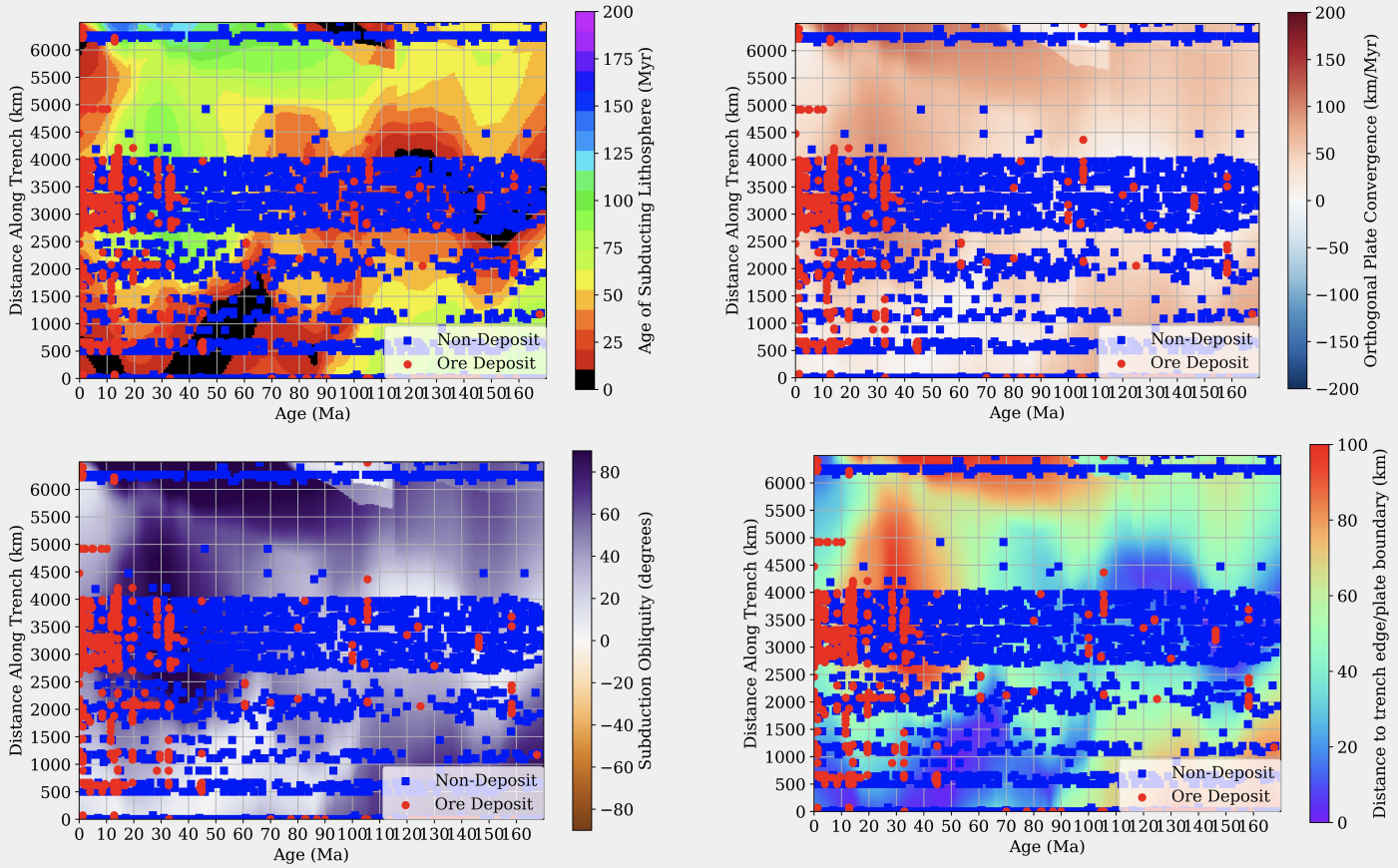


Figure 10. Graphs showing the four most important tectonic parameters. (A) Age of subducted lithosphere, (B) Orthogonal plate convergence rate, (C) Subduction obliquity, (D) Distance to plate boundary, and how they have changed over time on a spatiotemporal plot of the cobalt dataset.

Figure 11. Map of locations of cobalt deposits with a grade of >0.1% in South America

	Worldwide	South America
Total	185 871	4 919
Over 1000 ppm	1 429	2

Table 1. Number of deposits in the data set

MACHINE LEARNING

Support Vector Machines

- Nonlinear binary classifier
- Used to make probabilistic classifications

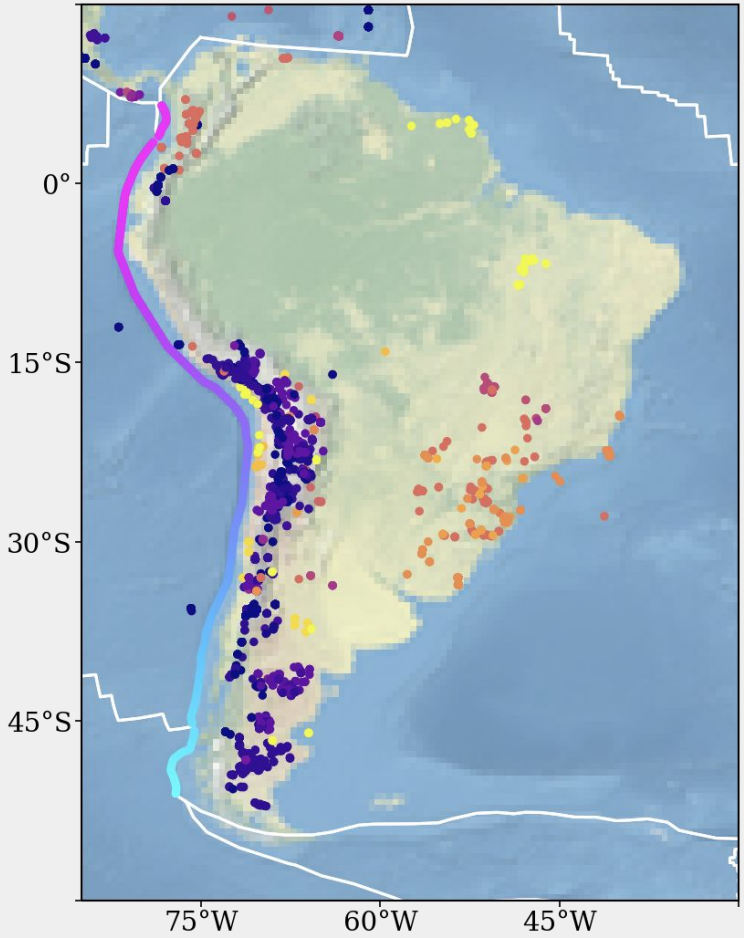
Random Forests

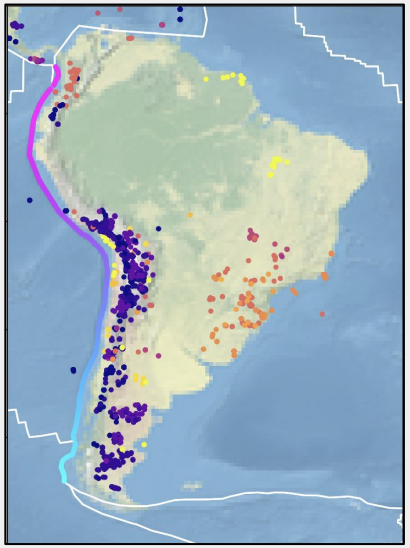
- Used to assess importance of individual parameters

	Cross validation score	
Method	**Point of Formation Data**	**Partitioned Data**
Random Forests	0.79 ∓ 0.03	0.68 ∓ 0.12
SVM	0.77 ∓ 0.04	0.75 ∓ 0.08

Table 2. Table showing the results of the five-fold cross validation process, a method to estimate the accuracy of machine learning predictions.

RESULTS





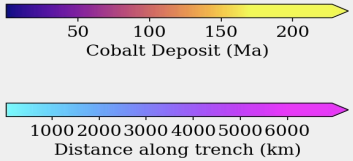


Figure 12. Map of cobalt deposits in South America

Figure 13.

Figure 14.

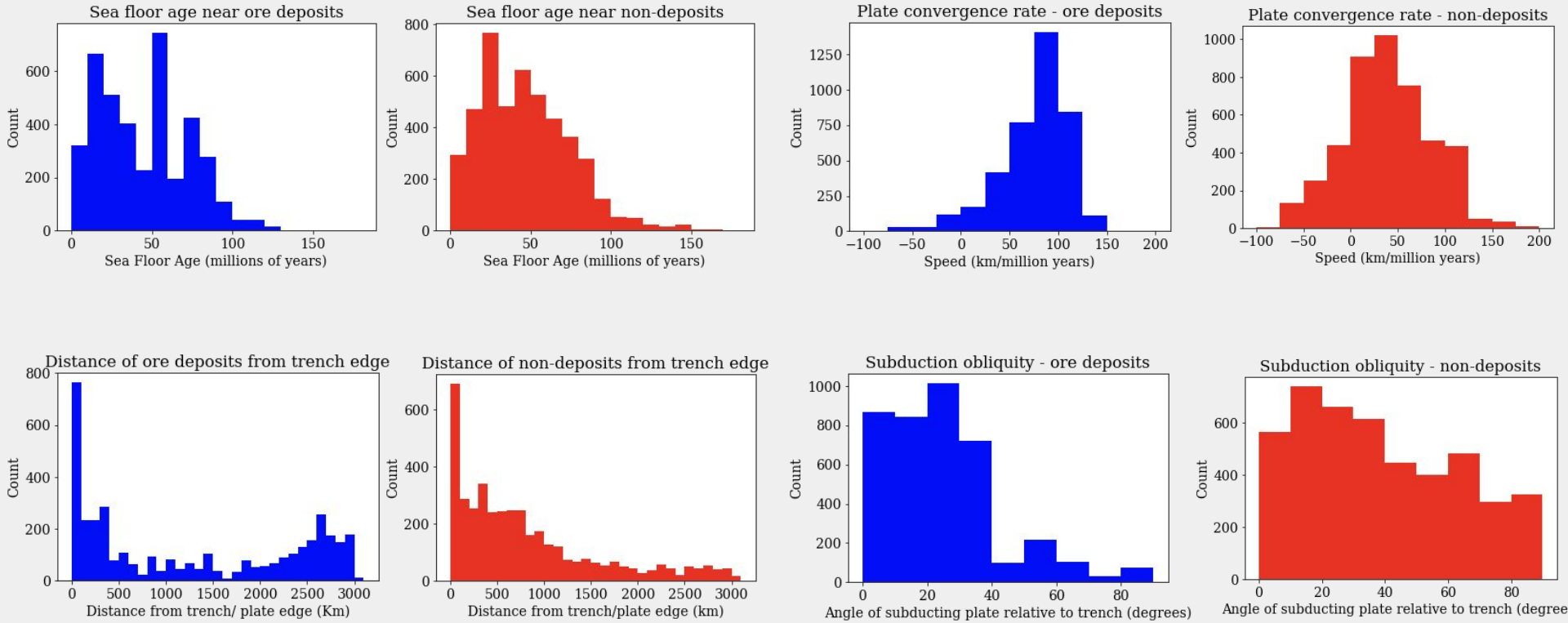
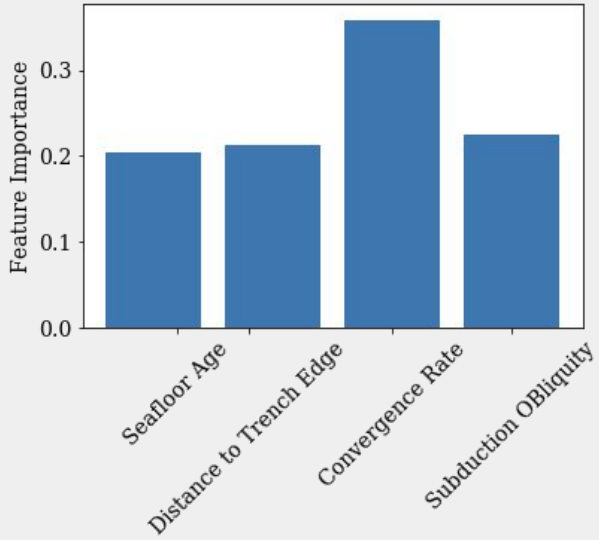


Figure 15. Histograms of each parameter, used in the machine learning, for the point of formation data for both the ore deposits and random non-ore deposits. Non-deposit plots (red) show the general trend of the subducting slab, while peaks in the deposit plots (blue) show where this trend caused a spike in deposit formation.

MACHINE LEARNING RESULTS

Point of formation data



Partitioned data

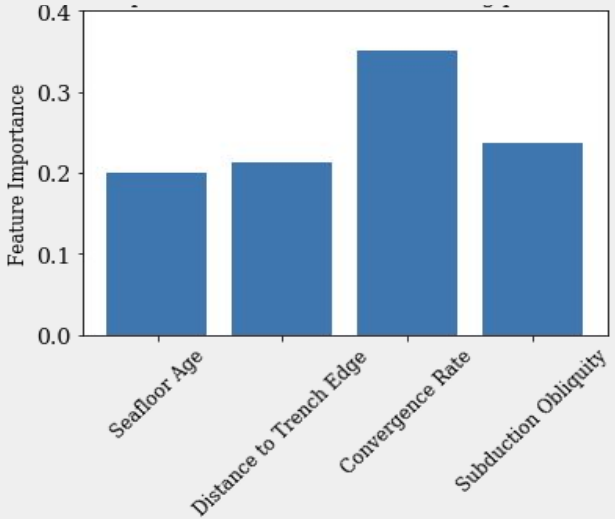


Figure 16. Graphs showing the relative importance of four tectonic parameters to the formation of cobalt deposits, using the different data classification methods.

MACHINE LEARNING RESULTS

Partitioned data

Point of formation data

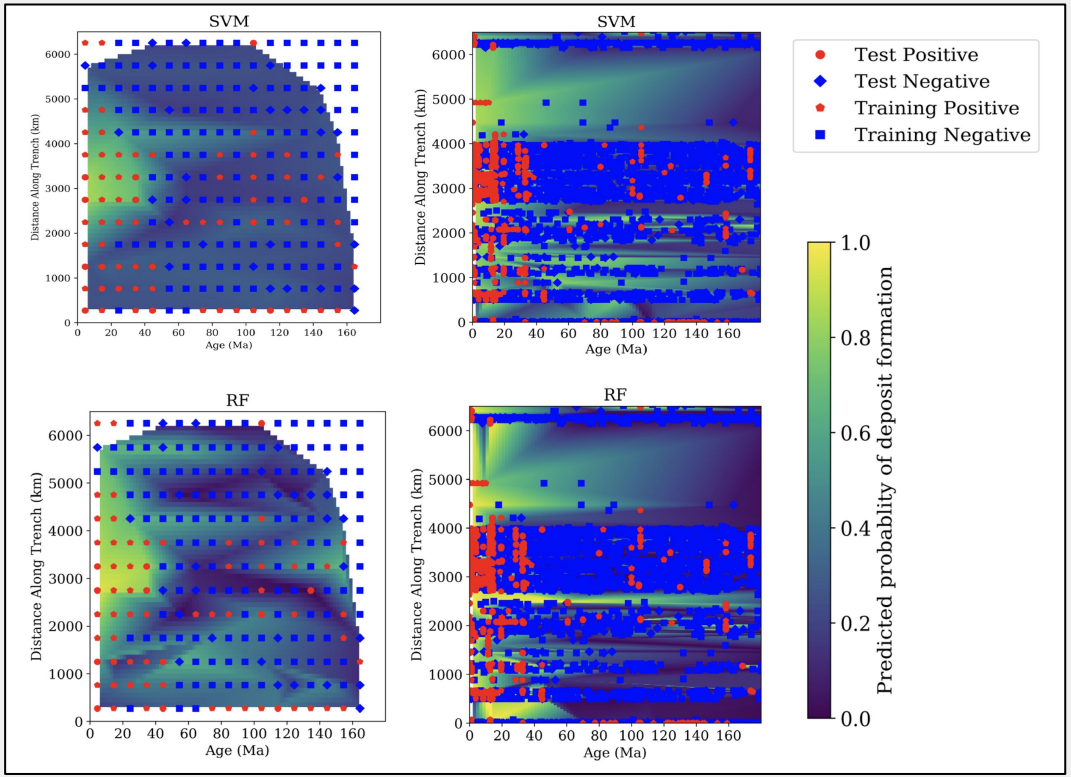
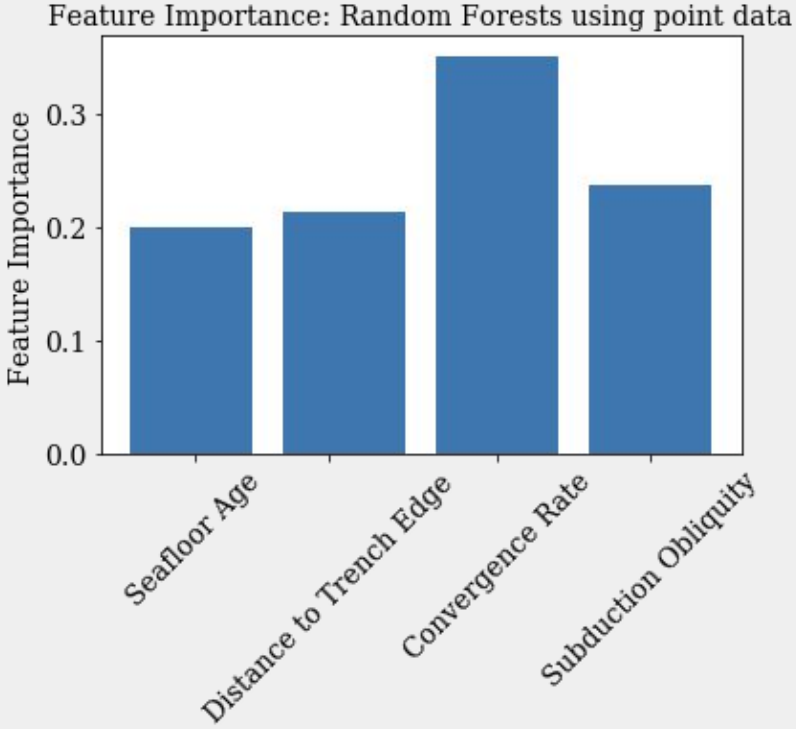


Figure 17. Diagrams showing the spatiotemporal probability of cobalt deposit formation, according to SVM and RF analysis.

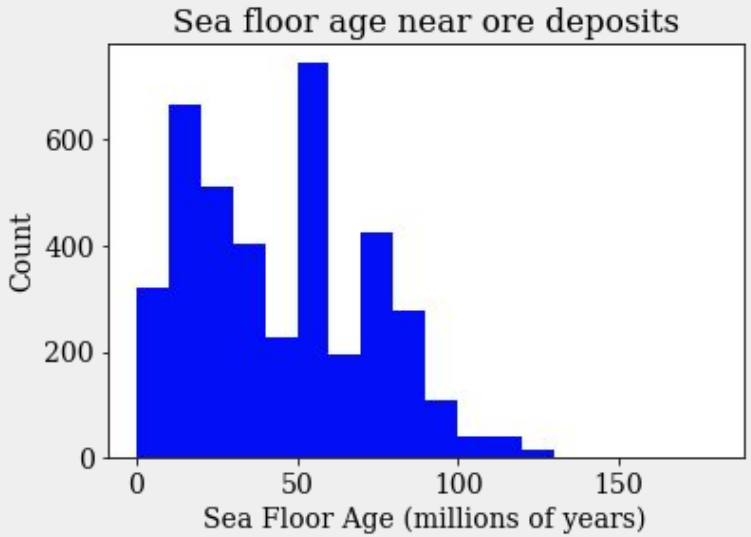
DISCUSSION

- Deposits formed over the past 140 million years concentrated on the west coast correlate with subduction processes
  - Hydrothermal activity
  - Small concentration of cobalt occurring in predominantly copper-gold porphyry type ore deposits
  - Geographically abundant, low concentrations

Relationships between subduction parameters and cobalt deposits



Seafloor age



Distance from plate boundary

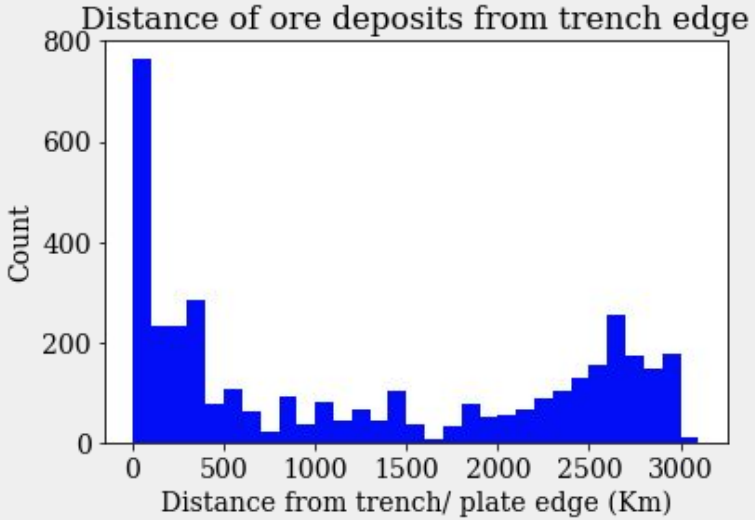
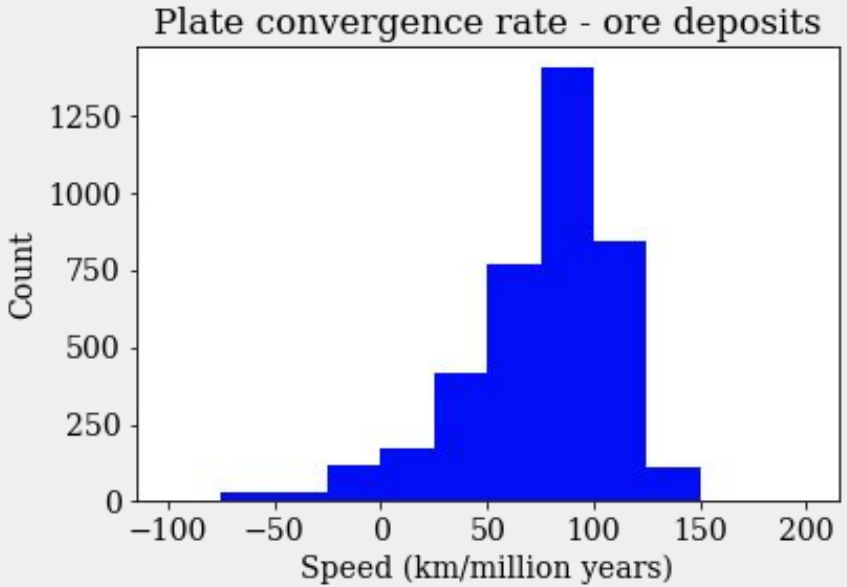
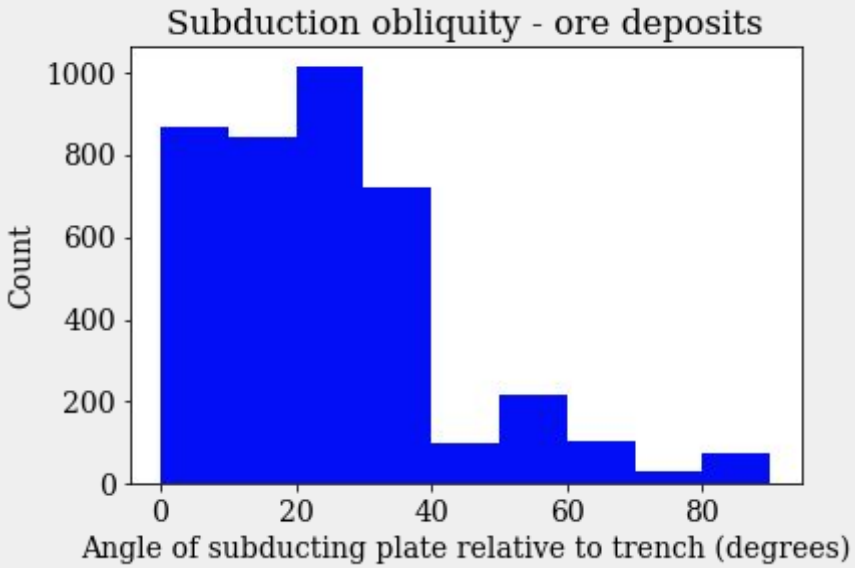


Plate convergence rate



Obliquity of subduction



CONCLUSION

Source: Zambian Mining Magazine (2017)

- Subduction produces deposits containing small concentrations of cobalt
  - Enriched cobalt deposits are not associated with subduction environments

Subduction zones are not regions that should be prioritised for mineral exploration