

RESEARCH ARTICLE

Web-based Application for Granite Tectonic Discrimination Visualization

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Abstract

One of categorization method for granitic rock is by their tectonic setting which can be analyzed by plotting their trace element value in discrimination diagram. Discrimination diagrams proposed by Pearce et al., particularly Rb vs (Y+Nb) and Rb vs (Yb+Ta) diagram, have been widely used by igneous geochemists. To produce the trace element plots in discrimination diagrams, many researchers use desktop software such as GCDKit, PetroGraph, GeopyTool, etc., which generate static diagrams. The deficiencies in using static diagrams are that the user cannot comparatively analyze the plotting result with another available data from different location or rock type and user also cannot group some identical data to allow more flexible analysis. Moreover, there are some more disadvantages when using desktop software which can only be accessed from one computer device and user cannot store and use data collectively. Web-based applications built using Node.js, MySQL and D3.js can be used to produce visualization for Pearce diagram interactively, store big data of trace elements into the database and access by many users. Using D3.js library, web bases application can generate diagrams with plots and/or density plots which allow more comprehensive comparative analysis between some corresponded geochemical data.

Keywords: Geochemical, Data Analysis, Web Application

1. Introduction

In research of granitic rock, trace elements are often used to determine rock classification. Pearce et al. (1984) introduced granitic classification with their tectonic discrimination diagrams using trace element content relation between Rb, Ta, Nb, Yb and Y. Pearce et al. divided granitic rock according to their intrusive setting into four main group Ocean Ridge Granites (ORG), Volcanic Arc Granites (VAG), Within Plate Granites (WPG) and Collision Granites (COLG). Discrimination diagram in Rb-Nb-Y and Rb-Ta-Yb space is the best discriminate tectonic setting with almost complete separation of syn-collision volcanic arc, within plate and ocean ridge granite (Pearce et al., 1984). Pearce Diagrams use lines with determined coordinates to set the borders between each tectonic settings based on big data of granite samples (Fig. 1).

Despite some problems directly mentioned by the author, Pearce et al. tectonic discrimination remains popular among granite geochemists. One of the main problems is that the granite chemical composition typically reflects source rock characteristic which is controlled by tectonic setting where the case was not complex. For example, from evaluation carried out by Forster et. al (1997) on the use of Pearce discrimination diagram, rock samples originated from Supra Subduction Zone Ridge (SSZ) tectonic setting, which is one of Ocean ridge type, plotted on Volcanic Arc Granite (VAG). This could be caused by contamination from continental material which is derived from zone related to subduction. Another example, post-orogenic (Post-COLG) granites compositionally overlap with several other tectonic fields that may be attributed to transitional nature of these granites (Hanson, 2016). Forster et al. has mentioned especially when the granitic rock formed in collision tectonic setting where magma source could derived

from variative different origin, the trace element data is usually plotted crossing tectonic setting filed in the discrimination diagram.

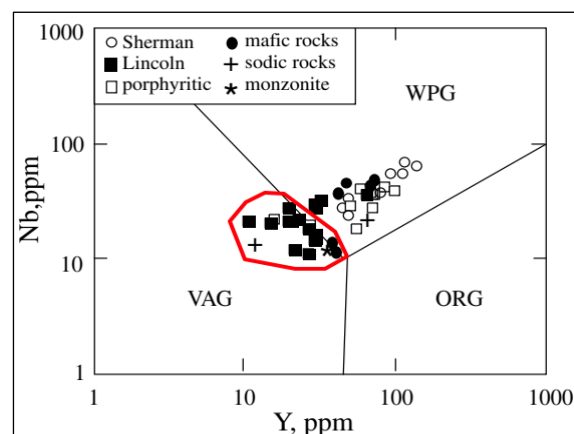


Fig. 1. Sherman and Lincoln granites which are part of one batholith plotted in different area in Nb versus Y discrimination diagram. Most samples of Lincoln granites (inside red circle) are in Volcanic Arc Granite area (from Frost et al. 1999).

Another example of this problem was stated by Frost et al. (1999) when analyzing petrogenesis of Sherman Batholith, SE Wyoming, United States. In another discrimination diagram options mentioned by Pearce et al. (1984), Nb versus Y discrimination diagram, most of the samples plot in the within-plate granite (WPG) while Lincoln granite samples lie between within-plate and volcanic arc granite fields (Fig. 1). Even though these granites are part of a single batholith, trace

element data shows dispersion in discrimination diagram. Thus, Lincoln granites must have been produced by partial melting of country rock that originated from volcanic arc (Frost, 2014). This shows how this discrimination diagram could have some

ambiguities linked to a complex, polyphase orogeny or the matter of differentiation with field boundaries crossing the VAG to WPG boundary (Ilboudo et al., 2021)

Table 1. Source of trace element data used to evaluate the Web-based Application

Location	Author	Tectonic Setting	Number of Data	Diagram	Data usage
Western Granitoid Belt of Thailand	Uchida dkk., 2024	Syn-Collision	15	Rb-(Yb+Ta)	Target data
White Creek Batholith, North America	Brandon dkk., 1994	Arc-Continent Collision	18	Rb-(Yb+Ta)	Comparative data
Notch Peak Granitic Stock, United States	Nabelek dkk., 1986	Continental Arc	53	Rb-(Yb+Ta)	Comparative data
Baoji Batholith, China	Gong dkk., 2024	Post-Collision	12	Rb-(Y+Nb)	Target data
White Creek Batholith, North America	Brandon dkk., 1994	Arc-Continent Collision	27	Rb-(Y+Nb)	Comparative data
Pan-africa Stratoid Granite, Madagascar	Nedelec dkk., 1995	Post-Collision	38	Rb-(Y+Nb)	Comparative data

Table 2. Example of software for geochemical analysis and comparison with web-based application.

Software Name	Author	Language	Desktop or Web	Limitations
Geopytool	Yu et al. 2018	Python	Desktop	- Static diagram (with interactive only for showing legend and data index). - No database. - Require other software installation (Phyton).
CGDK	Qiu et al. 2013	VBA	Desktop	- Static diagram (with interactive only for single diagram customization in CorelDRAW). - No database. - Require other software installation (CorelDRAW, Microsoft Excel).
GeoKit	Lu, 2004	VBA	Desktop	- Work only with the old version of CorelDRAW. - Static diagram (with interactive only for single diagram customization in Microsoft Excel). - No database. - No tectonic discrimination diagram. - Require other software installation (Microsoft Excel). - Work only with the old version of Microsoft Excel.
GCDPlot	Wang et al. 2008	VBA	Desktop	- Static diagram (with interactive only for single diagram customization in Microsoft Excel). - No database. - No tectonic discrimination diagram. - Require other software installation (Microsoft Excel). - Work only with the old version of Microsoft Excel.
GeoPLot	Zhou and Li, 2006	VBA	Desktop	- Static diagram (with interactive only for single diagram customization in Microsoft Excel). - No database. - Require other software installation (Microsoft Excel). - Work only with the old version of Microsoft Excel.
PetroGraph	Petrelli et al. 2005	MS Visual Basic	Desktop	- Static diagram (with interactive only for single diagram customization). - No database. - Work only with old version and limited computer operation system (Microsoft 2000 and Microsoft XP).
GCDKit	Janousek et al. 2003	R	Desktop	- Static diagram (with interactive only for single diagram customization). - No database. - Require other software installation (R).
PetroPlot	Su et al. 2003	VBA	Desktop	- Static diagram (with interactive only for single diagram customization in Microsoft Excel). - No database. - Require other software installation (Microsoft Excel). - Work only with the old version of Microsoft Excel.
Comparison with Web based Application				
Software Name	Author	Language	Desktop or Web	Advantages
Web Based App with Node.js and D3.js	-	JavaScript	Web	- Dynamic diagram (user can directly customize the diagram without re-computing it). - Use database (MySQL). - Users can combine data visualization from several sets of data available in the database. - Users are not required to install any software; they only need web browser and internet access. - Not depending on the software version or computer specification. Users don't need to update software. - Can be access from many types of hardware: computers or mobile devices

To use Pearce et al. diagram for geochemical research, geochemists usually use geochemical data software to visualize trace element data in discrimination diagram (Table 1). All those free for use software in the table work offline on user hardware and produce static graph that cannot be modified interactively by the user to produce more flexible analysis. Desktop application have two typical weakness which are 1) Application must be installed in user computer so that software performance and capacity depends on computer specification and 2) Access is limited on one computer making collective data analysis is difficult. Some more limitations of this type of software are explained in Table 2.

Web-based applications are often used to create software that can be accessed by multiple users as it uses one computer server to run the software and can be accessed by many users from web browser. Web-based applications also can be used to collect and store big data as they can be connected with database management systems like MySQL, MongoDB, SQL Lite and etc. To make dynamic visualizations on web application, a library using programming language like JavaScript is often used.

JavaScript is one of many programming languages that can create interactive web pages on web browsers. This language also can be used to build the software on the server side. One of the popular languages can be used to develop software on the server side, and based on JavaScript is Node.js. Node.js allows developers to use one language to develop web-based applications from server to user side on the browser. Web application using Node.js. usually develop using web framework to reduce complexity, more efficient and faster development. In this research Node.js is used with Express.js as web framework. Express.js is used for its simplicity and minimalist approach and its ability to handle heavy load systems like big data (Zima and Barszcz, 2024)

To make interactive data visualization on the web page JavaScript library D3.js is used. D3.js is a JavaScript library which is used to make data visualization. In creating visualization, D3.js uses standard visualization on web pages like SVG and Canvas. D3.js can be used to create data attractive and interactive visualization using “entering”, “updating”, and “exiting” operation on html elements. And to save big data into web applications in this research MySQL is used to store data into schemes and tables.

2. Method

This research is aiming to address the problem of using Pearce et al. discrimination diagrams by developing simple web application using JavaScript to visualize and analyze trace element geochemical characteristic on Pearce et al. (1984) tectonic discrimination diagram and then evaluate how this application resolves the miss-interpretation problem as mentioned by Forster et al. (1997). This research focus on two discrimination diagram: Rb vs (Y+Nb) diagram and Rb vs (Yb+Ta) diagram. This Web Application is built using Node.js as runtime environment on server side and arrange inside Express.js as framework. This application is using MySQL to manage trace element data into schemes and tables inside the database. The data then will be visualized into diagrams on web pages using D3.js library (Fig. 8). The Pearce et al. XY-diagram is shown in svg tag using coordinated borderlines.

This Web Application is then tested by inputting selected trace element data into the database through the application and then visualized into Pearce et al. (1984) diagram in the form of plots and contours. The published data we use is data from well-known complex tectonic settings that carry the problem targeted by this research (Table 1). These data visualizations are then evaluated on their effectiveness in resolving miss-

interpretation problem of trace element data from complex origin. Instead of making full online web application, a prototype that works locally will be developed as this research is exclusively to see how data visualization using web-based application can solve the tectonic discrimination problem.

3. Results and Discussions

3.1. Assessing the Problems

The problem when visualizing trace element data in static Pearce et al. diagram, as mentioned before, is the plotting result, which is automatically processed by the current software, not ultimately reflect the correct tectonic setting. When comparison with some typical trace element data is not available, geochemists could make wrong interpretation when analyzing data from complex tectonic settings. This case could be avoided when one trace element data can be overlaid onto another data to create comparative analysis using some well-known published data from similar tectonic settings. It's obvious the Pearce discrimination diagrams themselves were made using comparisons between bulk data of trace elements to produce tectonic discrimination areas. When a set of trace element data is plotted on Pearce diagrams, those data is being compared with data used by Pearce et al. (1984).

When comparing two or more trace elements data on tectonic discrimination diagrams, using static diagram can hardly result in relation between them like granitic rock research conducted by Nugroho et al. (2021). Geochemists sometimes use published geochemical data as a comparison to confirm the interpretation they made in their analysis. For example, Wenner and Lloyd (2006) use some published Proterozoic A-type granites to see the relation between a group of granitoids (Berlin and Redgranite) compared with other group of granites from two different tectonic setting, within-plate granite of Pikes Peak and St. Francois granites, and continental arc of Trans-Hudsonian and Penokean granites. With the use of published data as comparison on Pearce discrimination diagram, Wennner and Lloyd can see the research object is related to those which originated from within plate tectonic instead of continental arc (Fig. 2).

In that research Wenner and Lloyd (2006) used two types of visualization on discrimination diagram. First is colored plotting dots to present geochemical data from research object granites and second is colored polygon/field to present geochemical data from published researches. By using this method, the direct relation between those granites can be clearly seen. Thus, to address the problem in this research, data visualization software that allows users to compare several trace element data directly using combination of area and plotting visualization is proposed as the solution. A web-based application is most suitable for this purpose as it not only can produce interactive dynamic diagrams using D3.js, it also can collect and store big geochemical data using database as data reference for comparative analysis.

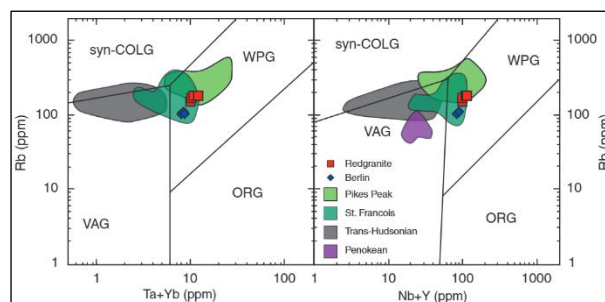


Fig. 2. Example of comparative analysis using known published data on Pearce et al. discrimination diagrams (from Wenner and Lloyd, 2006).

3.2. Developing Web-based Application

Like most web-based applications built on Node.js, this application is built using web framework to reduce complexity and reduce development time. Express.js web framework allows developers to use standard framework so they can focus on typing the application code. Combined with Node.js, it is also a preferable choice to develop web applications for extensive data structure like geochemical data (Kostrzewa and Milosz, 2024). And as this web-based application purpose is to test it for geochemical data analysis, author focus more on application function rather than user interface, as the result this application is built to be a simple web app. It is using multiple web pages to separate some functions, which are: 1) index page used as main page and for selecting diagram, Rb vs (Y+Nb) diagram or Rb vs (Yb+Ta) diagram, to use, 2) chart page use to show diagram and available data to be selected. 3) input page use to save or upload trace element data and store it into the database and to delete selected data from database.

For collecting and storing data into the database, this application uses two methods: First by using html form for user to input data information manually and save it into the database, and second by allowing user to upload csv file with fixed format and save all data inside csv file into the database. For visualization of trace element data into Pearce et al. diagram, data will be sent from database in form of web route or web URL in Json format. This data then will be used by D3.js libraries on the web page to visualize data into diagram. There are two type of visualization; first by creating dots based on coordinates from trace element data and second by, instead of creating plain area/field, it create density contour from group of trace element data using `contourDensity()` function. Density contour is used because it has more capability to show area based of trace elements data density, so it has more potential to help discrimination interpretation.



Fig. 3. Research workflow

3.3. Using the Web Application

Users can input geochemical data into the database in two ways: first is submitting data manually using input form on web application “input” page, or by uploading tubular dataset using csv file format using upload (*unggah*) feature on “input” page. Users can access and delete any data from the database as shown on “input page”. Once trace element data is in the database, users can plot them into Pearce et al. diagram by

selecting the diagram from the main page. Users can choose between Rb vs (Y+Nb) diagram or Rb vs (Yb+Ta) diagram to visualize data based on available trace element data in the database. Data visualization in Pearce et al. diagram will be shown in the form of plots on “chart” page (Fig. 4 and Fig. 5). Users can select which data they want to plot into the diagram using checkbox on “data sampel” panel and the selected data will be plotted into the diagram. To divide selected data into groups, user can freely change plot color of each data using color input box on “data sampel” panel.

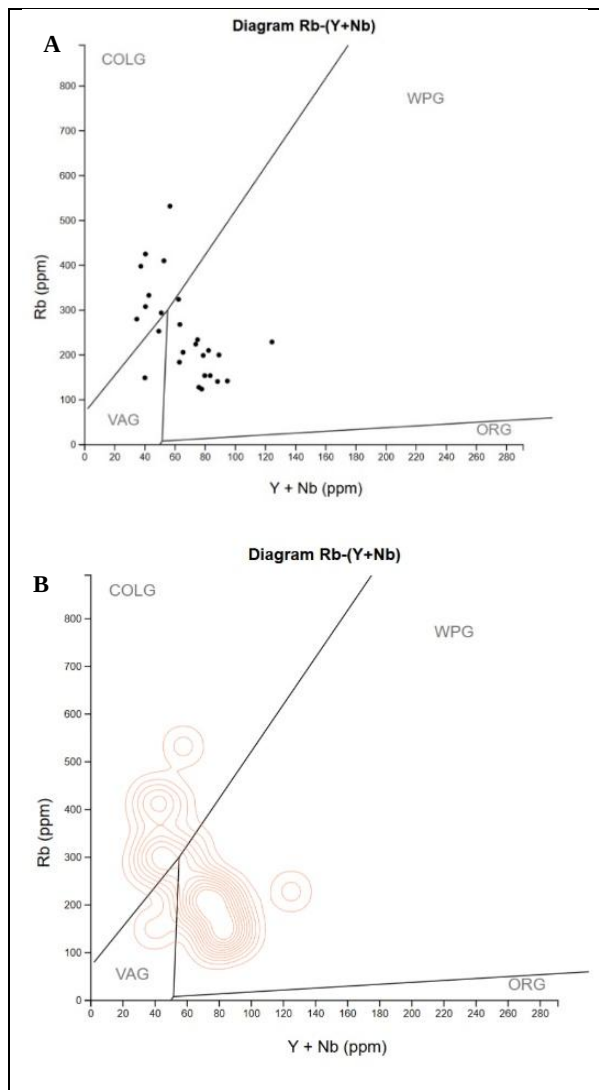


Fig. 4. Trace element visualization of Batholith White Creek in Rb (Y+Nb) diagram. A) Plotting points visualization, and B) Density plot / contour density visualization.

Users can create a group of data based on location, intrusive suite, geochemical characteristic or other unlimited parameters by selecting data using checkbox and click “group” button. This action will open a modal pop-up window where user can fill form with group information like group name and description. Each group that was created will be saved in the database and will remain one group the next time user uses the application. When the user wants to see these groups in the diagram, these groups will be shown as density contour. When there are multiple groups available, users can put these group overlay to show the correlation between two or more group data.

Density contour or density plot in D3.js is density visualization of plotting points in geometry form as contour lines or group of contours. This web application density data was produced by computing plotting coordinates using contour

Density () function in D3.js library. Every geometry represents plots number per square pixel, the more plots in one area then the contour will be denser. These contour lines will have a top of contour which can be interpreted as the densest area in the plots.

Users can combine multiple groups into one diagram where the last selected group will be placed on top of the previous group. Each group will have different colors which are automatically arranged by the application so the user can easily differ each group. Users can also combine groups and plots where plots will always be placed on top of group. Users can interactively select and remove data as group or contour by using checkbox on “data sampel” and “group sampel” panel.

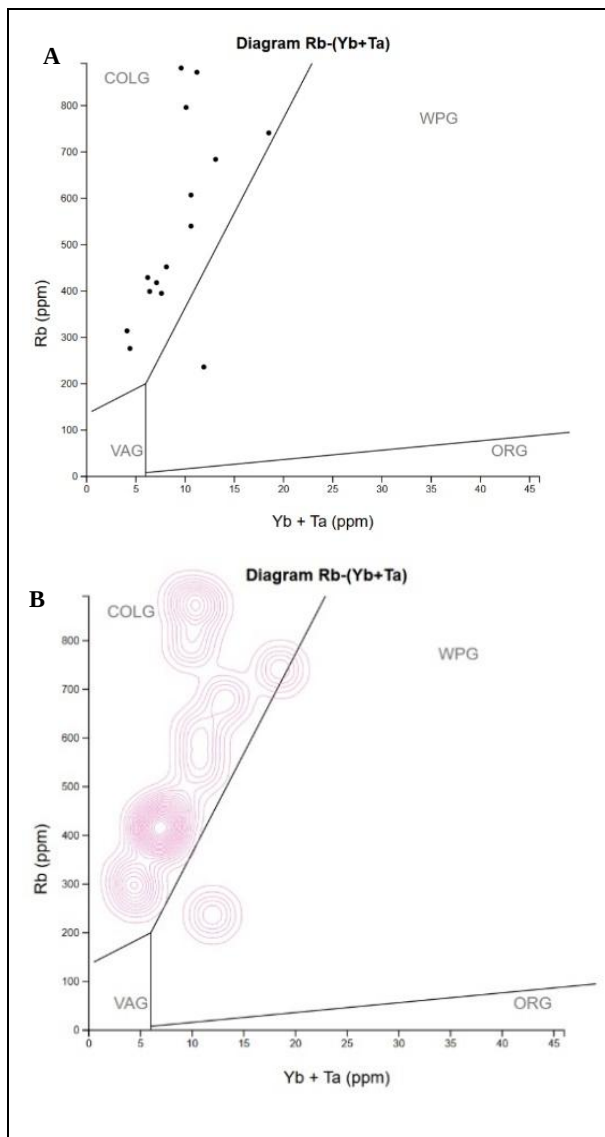


Fig. 5. Trace element visualization of Western Granitoid Belt of Thailand in Rb (Yb+Ta) diagram. A) Plotting points visualization, and B) Density plot / contour density visualization.

3.4. Data Visualization Results and Evaluation

Trace element data from two location is used to show plots in Pearce et al. diagram: 1) Data originated from White Creek batholite in South Canadian Cordillera into Rb vs (Y+Nb) diagram, and 2) data originated from Western Granitoid belt of Thailand into Rb vs (Yb+Ta) diagram. White Creek Batholite is felsic and originated from collision and accretion zone between island arc and continent (Forster et al., 1997). In Rb vs

(Y+Nb) diagram (Fig. 4A) plotting points of this plutonic trace element are inside Within Plate Granite (WPG) and Collision Granite (COLG) excluding two samples plotted inside Volcanic Arc Granite (VAG) area which are very peraluminous aplite (Brandon et al., 1994). Using group density contours, this sample shows the densest contours inside WPG area (Fig. 4B).

In Rb vs (Yb+Ta) diagram (Fig. 5A) which show trace element data from Western Granitoid Belt of Thailand, plotting points are spread along borderline between COLG and WPG with most of the points are plotted on COLG side except one sample with lower Rb. Meanwhile contour density (Fig. 5B) shows the densest area is shown when Rb value is between 395-452 ppm inside COLG area.

To evaluate how this web-based application does a comparative analysis we used trace elements data collected by Forster et al. (1997), to evaluate Pearce et al. (1984) discrimination diagram, as “published” or comparative data. And as target data we pick some published data that could be related to comparative data above.

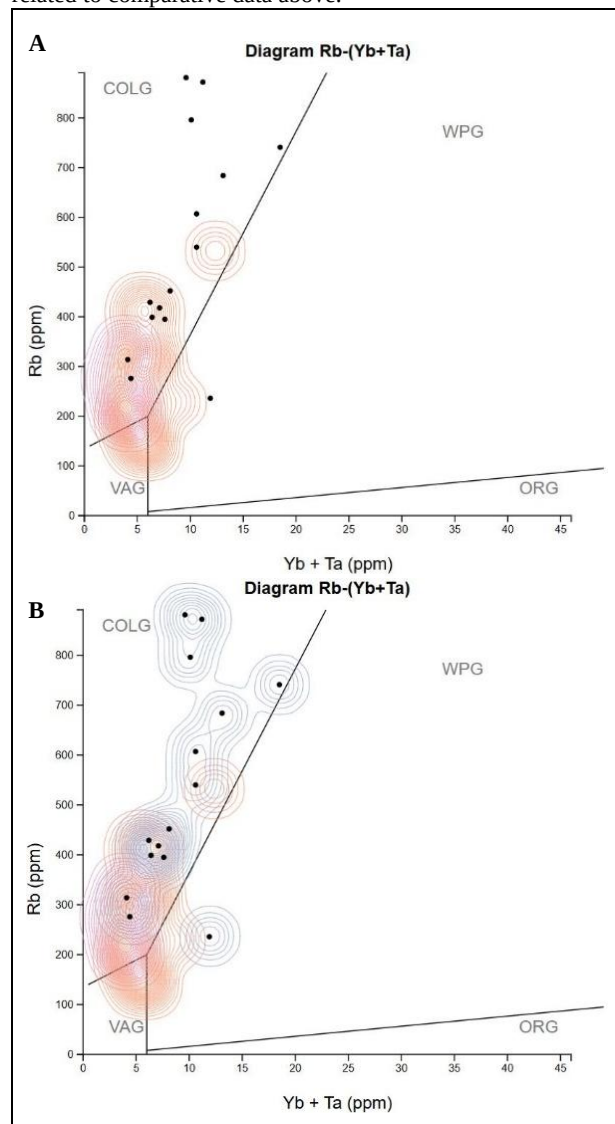


Fig. 6. Visualization results of Western Granitoid Belt of Thailand (WGBT) (dots and blue contour) compared to White Creek Batholith (WCB) (orange contour) and Notch Peak Granitic Stock (NPGS) (purple contour). A: when using plotting dots to visualize WGBT and B: when using density contour.

In the first comparative analysis trace element data from Western Granitoid Belt of Thailand (WGBT) was used., which is part of three granitoid belt in Thailand along with Eastern

Granitoid Belt and Center Granitoid Belt (Charusiri et al. 1993). This granitoid belt is known as one of the main world Sn (Tin) sources (Cobbing et al., 1983; Gardiner et al., 2015). While eastern belt of Thailand belongs to Indochina block, this western part was laid on Sibumasu (Metcalf, 2013; Searle et al. 2012; Shi et al., 2021). This primary S-type tin rich granitoid belt was formed during collision (syn-collision) between West Burma block and Sibumasu at late Cretaceous (Uchida et al. 2024). As for comparative data, geochemical data from White Creek Batholith (WCB) and Notch Peak Granitic Stock (NPGS), of Cordillera was used. Both data were used by Forster et al. (1997) to evaluate Pearce tectonic discrimination diagram. White Creek Batholith was formed in complex tectonic setting where crustal thickening was taking place following terrane accretion and collision (Forster et al. 1997). When classified using Pearce discrimination diagram, Rb versus (Yb+Ta) diagram, this silica-rich granite mostly is plotted in Volcanic Arc Granite (VAG) field but not few is plotted in Within Plate Granite (WPG) and Syn-Collision Granite (Syn-COLG). This overlapping reflects the mixed source of its magma. Notch Peak is situated inward in North American craton but has volcanic arc traces in its geochemical. On Rb versus (Yb+Ta) discrimination diagram most of the samples are plotted in Syn-COLG field with few are plotted in VAG field. This may be as the effect of arc magma source erupted through different crustal domains (Forster et al., 1997).

Using web-based application we developed, we compared target data (WGBT) with comparative data (WCB and NPGS) where the former was visualized as plotting dots, and the latter was visualized as density contour (Fig. 6). About half of WGBT (8) samples were plotted inside WCB contour area and two of them were also plotted inside NPGS contour area. While visualizing both data as density contour, the densest point of WGBT (between 400-430 ppm of Rb) still appeared in WCB area, and although this point has relative the same distance with the densest point of WCB and NPGS, it can be interpreted based on data visualization, using this web-based application, that WGBT has closer relation with WCB than NPGS. Both WGBT and WCB have collision tectonic settings (Mitchell, 1979; Uchida et al. 2024) but WCB is placed lower in discrimination diagram and has crossed VAG and WPG field maybe due to contamination from Arc material (Nabelek, 1986; Henze, 2020))

Another example to evaluate data visualization result, using Rb versus (Y+Nb) discrimination diagram, we compared trace elements data from WCB and Madagascar Granite (MG) as published data with trace element data from Baoji (BJ), China (Fig. 7). BJ is situated in Qinling Orogenic Belt which is lied between North China Block and South China Block and plays significant role in the continental reconstruction of China (Dong and Santosh, 2016). This orogenic belt has experienced multiple stages of accretion and collision between South and North China as well as intervening microcontinents since the Proterozoic, finally leading to its formation in Early Mesozoic (Wu and Zheng, 2013; Dong and Santosh, 2016). Granite in this zone has A-type affinity with high Nb/Ta and Ga/Al ratios. By using plotting dots to visualized BJ and density contour to visualized WCB and MG, we compare this data visualization. Nine of twelve data from BJ is plotted inside WCB and MG fields, and when using density contour to visualized BJ, the densest contour from BJ is closer to densest data contour of WCB than MG. But overall, BJ density contour has more contact with MG than WCB with relative similar data distribution. This can interpret as BJ has slightly closer relation with MG as they both derived from post-collision tectonic setting (Gong et al., 2024; Nadelec et al., 1995; Brandon et al., 1994).

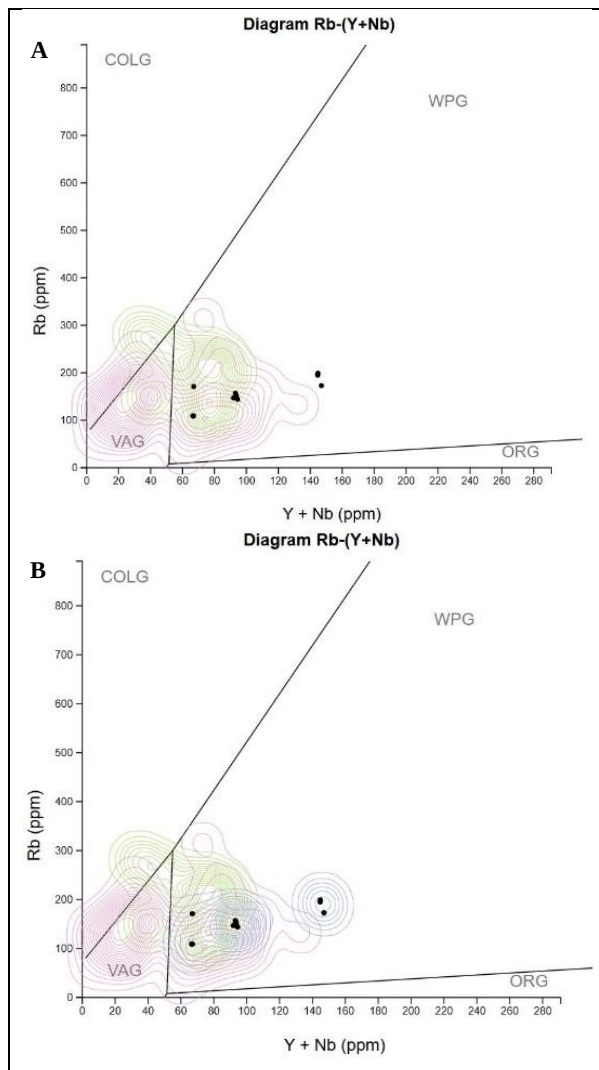


Fig. 7. Visualization results of Baoji Granites (BJ) (dots and blue contour) compared to White Creek Batholith (WCB) (green contour) and Madagascar Granite (MG) (purple contour). A: when using plotting dots to visualize WGBT and B: when using density contour.

Based on two comparative analysis examples above, a user can use density contour to visualize published trace element data to compare it to object trace element data. Density contour can give the researcher a better insight into how data is distributed by analyzing how contour spreads and where the densest contour is placed. Users can also analyze how close object data is plotted with density contour and how similar the data is distributed. Users also have flexibility to choose and changes how data is visualized giving more viewpoints of how data related to each other.

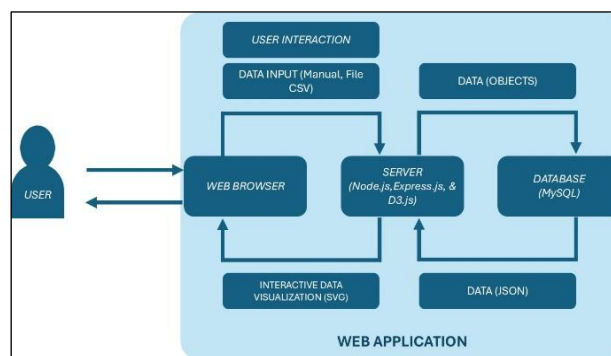


Fig. 8 Tectonic discrimination web-based application workflows

4. Conclusions

The use of this web-based application clearly helps determine the relation between two or more trace element data. Even though the analysis result is dependent merely on one geochemist interpretation, this method of using density contour produced by this application could give extra insights to see where the densest data and how it distributes along the contour field.

Moreover, analysing tectonic discrimination on Pearce et al. (1984) diagram using web-based application build by Node.js, MySQL and D3.js has some advantages when compared to conventional desktop software, which are:

1. Node.js web-based application with MySQL database can store big geochemical data and can be accessed by multiple users from different hardware, allowing more flexibility in collecting, storing and using data and can also act as data bank.
2. This web-based application with Node.js and D3.js allows data visualization on Pearce et al. diagram interactively where user can select, group and combine which data they want into data group that can be visualized as density plot.
3. Using this web-based application allows users to analyze big data of trace element by comparing data interactively using density plot as it reduces noises resulted by so many plotting points stacked together.
4. This web-based application can show groups of trace element data as density plot (contour density) which reflect data density on diagram. Contour density is effective for analyzing data distribution.
5. This Web-based application can be further developed to include others discrimination and classification diagrams using geochemical data

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