INTRODUCTION

Mineralogists, geochemists and petrologists commonly use binary, spider and ternary diagrams to represent mineral data, whole-rock geochemistry and phase relations of chemical systems. Interpretation of these data requires visualization of large data sets in multiple dimensions. For the study of phase systems or for the modeling of geochemical data, it may be useful to represent rock or mineral analyses in tetrahedral diagrams.

A number of computer programs have been developed to plot the data, such as TETRASEZ (Armienti, 1986), CSpace (Torres-Roldan et al., 2006), CMAS 3D (France et al., 2009), MetaRep (France and Nicolette, 2010), TetPlot (written by Frank S. Spear) and TetLab (written by Peter Appel). These programs run on programming language platforms such as FORTRAN, BASIC, JAVA and Cocoa (application programming interface for the OS X operating system). All these programs are useful, but often not simple to handle. To copy or import the data into these programs can be very time consuming and the charts should get reworked with graphics software before they can be used for presentations.

A simple spreadsheet for tetrahedral diagrams has been introduced by Shimura and Kemp (2015). A new program is presented here “Tetra-Plot” a Microsoft Excel spreadsheet. It is a spreadsheet application allows to normalize and plot four different variables on tetrahedral diagrams. This spreadsheet has been designed to represent mineral and whole-rock geochemistry in igneous and metamorphic petrology.

Tetra-Plot was developed using Excel® 2011 for Apple Macintosh. It should work with all Excel versions for Macintosh and PC running Windows XP, 7, 8 and 10, as well as Apache OpenOffice. This program is simple to handle and do not use VBA macros. It has a familiar user interface and data can be easily cut-and-pasted into the excel spreadsheet. Tetra-Plot can be downloaded at http://periodicodimineralogia.it/index.php/mineralogia/issue/view/30/showToc.

Compared to the spreadsheet of Shimura and Kemp (2015), Tetra-Plot:

1. Can plot the data also in a single triangle face of the tetrahedron
2. Can plot isotope data on tetrahedral diagrams
3. The tetrahedrons can rotate around all axes
4. The charts show automatically the apex-titles
5. The data can be easily selected using drop down menu

TETRA-Plot SPREADSHEET

The Tetra-Plot spreadsheet consists of seven worksheets (Input data, Calculated data, Tetrahedron major elements, Tetrahedron trace elements, Tetrahedron isotopes, Tetrahedron CIPW and Note). The Input data and Calculated data worksheets contain the data entry and
calculation area. Data can be imported from the clipboard or entered from the keyboard. By default, up to 200 data points can be plotted (see for example Figure 1). However, the user can increase the input data easily by adding more rows in the Input data worksheet and, then copying and pasting the formulas in the Calculated data worksheet. The Tetrahedron major elements, Tetrahedron trace elements, Tetrahedron isotopes and Tetrahedron CIPW worksheets contain tetrahedral diagrams. These diagrams are standard XY scatter graphs and can be modified to change parameters such as symbols, colours, size, line thickness. Each tetrahedral diagram contains different data series (major elements in wt%, trace elements in ppm, etc.). The list of data series is reported in the Calculated data worksheet. Any data sets can be plotted on a single tetrahedral diagram. Then, the tetrahedral diagrams can be copied to the clipboard and pasted into a suite of software for presentations.

The user should not delete any columns or rows containing the calculations crucial to the construction or movement of the tetrahedron.

**TETRAHEDRAL PLOTS**

To plot data into a tetrahedral diagram occur four steps: 1) build the tetrahedron; 2) collect raw data (e.g. whole-rock and mineral data) for the four variable of interest; 3) normalize the raw data; 4) plot the normalized data on the tetrahedral diagram.

The tetrahedron is constructed with four equilateral triangle faces and four vertices (named A, B, C and D; Figure 2). The coordinates of the vertices are: A (0.0; -57.7), B (0.0; 0.0), C (50.0; -28.9) and D (-50.0; -28.9). The apex represents the 100% of a component. The user can easily select each apex using the drop down menu (Figure 3) in the Calculated data worksheet. The apex titles will be automatically displayed on the diagram.

The raw data of the four apexes (A, B, C and D) must be changed into normalized data. The equations to do this are:

\[
Y = \frac{(A \times 86.6025 + B \times 28.8675)}{(A + B + C + D) - 28.8675}
\]

\[
X = \frac{A \times 0 + B \times 0 + C \times 50 + D \times (-50)}{(A + B + C + D)}
\]

\[
Z = B \times (-81.6497) \div (A + B + C + D)
\]

The equations to change the unnormalized data to normal data.
normalized data for a triangle face (example BCD) of a tetrahedron are:

\[
Y = \frac{(B \times 28.8675)}{(B+C+D-28.8675)}
\]
\[
X = \frac{(B+0+C+D)(-50)}{(B+C+D)}
\]
\[
Z = \frac{(B \times 81.6497)}{(B+C+D)}
\]

The equations for the transformation of unnormalized data to normalized data are provided in the Calculated data worksheet.

Then, the data are converted into X-Y coordinates using the following equations:

\[
Y' = X' \cos(\gamma x p/180) \cos(\alpha x p/180) + Y \times \sin(\gamma x p/180) \times \sin(\alpha x p/180) + Z \times \cos(\gamma x p/180) \times \sin(\alpha x p/180)
\]

where \(\alpha\), \(\beta\), and \(\gamma\) are the angles for the rotation (Tetrahedron worksheets; column B, rows 3, 4, 5).

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**Figure 2.** Tetrahedral diagram with coordinates.

**Figure 3.** View of portion of Calculated data worksheet.
Figure 4. Di-Ab-Fo-Ab system drawn with Tetra-Plot before and after rotation.

Figure 5. Examples of tetrahedral diagrams for the igneous rocks from the Gharyan volcanic field. Data are from Lustrino et al. (2012).
**Rotation of the tetrahedron**

The elementary 3D rotation matrix is constructed to perform rotations individually about the three coordinate axes. The tetrahedron can rotate changing the angle values in the column B, rows 3-5 of the Tetrahedron worksheet.

In Figure 4 is shown the system Di-An-Fo-Ab before and after rotation of angles α (8°), β (143°) and γ (338°).

The user can design lines (e.g. cotectics), points (e.g., eutectics, peritectics) in a phase system by inserting the required plotting coordinates in the Input data worksheet. In the Tetrahedron CIPW worksheet, the coordinates required for the cotectic lines and eutectic points of Di-Qz-Ne-Ks and Di-Fo-An-Ab systems are reported in the Note worksheet.

**IMPLICATIONS**

Tetra-Plot spreadsheet provides a practical and simple method to plot tetrahedral diagrams. This program increases the ability of the user to easily display and interpret data for complex systems. Tetrahedral diagrams are useful for mineralogists, geochemists and petrologists to classify mineral or rock types and to investigate igneous and/or metamorphic processes.

Examples of tetrahedral diagrams generated by Tetra-Plot showing data of volcanic rocks from the Gharyan volcanic field (Lustrino et al., 2012) are represented in Figure 5.

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**REFERENCES**


