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Using Tourmaline As An Indicator Of Provenance: Development And Application Of A Statistical Approach Using Random Forests

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USING TOURMALINE AS AN INDICATOR OF PROVENANCE:
DEVELOPMENT AND APPLICATION OF A STATISTICAL APPROACH
USING RANDOM FORESTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements of the degree of
Master of Science

in

The Department of Geology and Geophysics

by
Erin Lael Walden
B.S., Louisiana State University, 2008
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In memory of Wayne Douglas Walden

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ABSTRACT

Tourmaline is a petrologic indicator mineral that is the major repository of boron in the earth's crust. It forms readily when boron is present, accommodating multiple cations and anions with multiple possible substitutions for each site in the crystal structure. It is stable over a wide variety of pressures and temperatures, from near-surface P/T conditions to greater than 950 C and 7 GPa. It records information about conditions of formation, as well as pressure and temperature. Due to its resistance to chemical or physical weathering, and the negligible diffusion of elements in the crystal lattice, information about provenance is preserved. In Henry and Guidotti (1985), major elements of tourmaline were used to construct ternary diagrams that classify tourmalines according to provenance. However, this technique does not make use of the entirety of available chemical data. New statistical techniques can make use of all available chemical information and provide information about element importance.

Using a novel application of an existing statistical method, random forests, to high-dimensional tourmaline data, provenance information is obtained. Existing chemical analyses are assembled into a database and labeled with their provenance. A random forest is 'grown' using a full database of tourmaline data, producing a set of rules for classifying tourmalines according to provenance. The random forest method has internal controls on accuracy and fitting of the data, and is capable of classifying tourmalines at a level of between 90 and 95% accuracy. As an independent test, a random forest built from this database is used to successfully classify tourmalines according to provenance.

CHAPTER 1 – INTRODUCTION

Sedimentary provenance studies are important in reconstructing the geologic history of a region by defining the specific source rock or type of source rock of clastic metasedimentary materials. Clastic sedimentary provenance studies typically rely on the mineralogical or lithologic composition of the detrital grains in the sediment, the whole rock chemical or isotopic characteristics, or the mineral and isotopic compositions of specific detrital materials in the sediment. (e.g. Morton and Hallsworth 1999). If the primary objective of provenance studies is the identification of a rock or mineral's original source, the secondary objective of provenance studies is the application of that provenance to more regional scales. A series of fundamental questions asked by early provenance researchers place provenance studies in perspective. "From what kind of source rock (or rocks) was the sand derived? What was the relief and climate in the source area? How far and in what direction did the source area lie? ...What kinds of observations must we make to find an answer to our questions?" (Pettijohn et al. 1987).

In sedimentary and metasedimentary rocks, as well as modern sediments, the ultimate source of material is a function of physical and chemical weathering, transport, sorting, and storage, including relief, slope, climate and vegetative cover (e.g. Johnsson 1993). However, the large majority of clastic material that is weathered out of the rock and transported is prone to chemical breakdown during weathering and transport, physical rounding, dissolution and diagenesis after sediment burial and loading (e.g Morton and Hallsworth 1999). Heavy minerals, which include garnet, hornblende, epidote, apatite, tourmaline, rutile, and zircon, are more resistant to chemical and mechanical weathering, persisting even through multiple weathering cycles and reworking of sediments (Morton and Hallsworth 1994, 1999). Among these,

tourmaline is one of the most promising candidates for provenance studies because of its stability and chemical complexity. It is stable over nearly all crustal pressure and temperature conditions, as well as acidic to neutral pH conditions in associated fluids (Dutrow and Henry 2011, Van Hinsberg et al. 2011a, 2011b). Tourmaline easily accommodates different cations and anions within its structure and offers robust retention of chemical information even after multiple weathering cycles, and this feature can complement the geochronological information that is accessible from associated detrital zircon. This combined style of investigation permits a more holistic approach to provenance. The objective of this study is to evaluate if a statistical procedure, random forests, can be used to access the entire range of chemical information available from tourmalines to build models that can be used to make increasingly accurate predictions of a tourmaline's provenance.

CHAPTER 2 – CRYSTALLOGRAPHIC AND PETROLOGIC BACKGROUND OF TOURMALINE

Tourmaline

The potential of tourmaline as a robust provenance indicator is derived from the nature of its mineralogy and crystallography as well as its wide range of petrologic occurrences. The tourmaline supergroup minerals, containing 34 species of tourmaline (Henry et al. 2011, see Table 2.1), constitute the most widespread borosilicate minerals in the Earth's crust. It has a Mohs hardness of 7-7 ½ and indistinct cleavage on {110} and {101}. It is frequently prismatic and color-zoned; these color zones may correspond to compositional zoning, although compositional zoning may be on a much finer scale than suggested by the color zoning. Characteristic striations parallel to c-axis and hemimorphic crystal terminations make it easy to identify in hand sample.

Tourmaline is an acentric rhombohedral cyclosilicate (space group = R3m) (e.g. Dietrich 1985, Henry and Dutrow 1992). The crystal is strongly polar, and exhibits pyroelectric and piezoelectric qualities, meaning that the crystal develops charges at the poles when subject to temperature variation or pressure changes along the c-axis (see Figure 2.1 for crystal structure). When cooled, the antilogous (+c) pole of the crystal develops a positive charge, and the analogous (-c) pole a negative one. Application of pressure to the crystal along the c-axis will cause the antilogous pole (+c) to develop a positive charge and the analogous (-c) pole to develop a negative charge (Barton 1969). Hawkins et al. (1995) found that these properties were strongly related to the locations of ions in tourmaline's structure (Figure 2.1).

Table 2.1 – Currently recognized and predicted tourmaline species grouped by X-site occupancy, according to the nomenclature recommendations (Henry et al. 2011.) These named tourmaline species are currently recognized by the International Mineralogical Association's Commission on New Minerals, Nomenclature and Classification (IMA-CNMNC). The unnamed species have been predicted.

	General formula	(X)	(Y ₃)	(Z ₆)	T ₆ O ₁₈	V ₃	W
Alkali group	Alkali subgroup 1	R ¹⁺	R ₃ ²⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Dravite	Na	Mg ₃	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Schorl	Na	Fe ₃ ²⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Chromium-dravite	Na	Mg ₃	Cr ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Vanadium-dravite	Na	Mg ₃	V ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Fluor-dravite	Na	Mg ₃	Al ₆	Si ₆ O ₁₈	(OH) ₃	F
	Fluor-schorl	Na	Fe ₂ ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	F
	Potassium-dravite	K	Mg ₃	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Tsilaisite	Na	Mn ₃ ²⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Fluor-tsilaisite	Na	Mn ₃ ²⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	F
	Alkali subgroup 2	R ¹⁺	R _{1.5} ¹⁺ R _{1.5} ³⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Elbaite	Na	Li _{1.5} ¹⁺ Al _{1.5} ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Fluor-elbaite	Na	Li _{1.5} ¹⁺ Al _{1.5} ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	F
	Alkali subgroup 3	R ¹⁺	R ₃ ³⁺	R ₄ ³⁺ R ₂ ²⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ²⁻
	Povondraite	Na	Fe ₃ ³⁺	Fe ₄ ³⁺ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Chromo-alumino-povondraite	Na	Cr ₃	Al ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Bosiite	Na	Fe ₃ ³⁺	Al ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Oxy-dravite	Na	Al ₃	Al ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Oxy-schorl	Na	Al ₃	Al ₄	Si ₆ O ₁₈	(OH) ₃	O
	Oxy-chromium-dravite	Na	V ₃	Cr ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Oxy-vanadium-dravite	Na	V ₃	V ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Vanadio-oxy-dravite	Na	V ₃	Al ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Vanadio-oxy-chromium-dravite	Na	V ₃	Cr ₄ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Potassium-povondraite	K	Fe ₃ ³⁺	Fe ₃ ⁴⁺ Mg ₂	Si ₆ O ₁₈	(OH) ₃	O
	Maruyamaite	K	(MgAl ₂)	(Al ₅ Mg)	Si ₆ O ₁₈	(OH) ₃	O
	Alkali subgroup 4	R ¹⁺	R ₁ ¹⁺ R ₂ ³⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ²⁻

	General formula	(X)	(Y ₃)	(Z ₆)	T ₆ O ₁₈	V ₃	W
	Darrellhenryite	Na	Li ₁ Al ₂	Al ₆	Si ₆ O ₁₈	(OH) ₃	O
	Alkali subgroup 5	R ¹⁺	R ₃ ³⁺	R ₆ ³⁺	R ₆ ³⁺ O ₁₈	S ₃ ²⁻	S ¹⁻
	Fluor- buergerite	Na	Fe ₃ ³⁺	Al ₆	Si ₆ O ₁₈	(O) ₃	F
	Olenite	Na	Al ₃	Al ₆	Si ₆ O ₁₈	(O) ₃	(OH)
	Buergerite	Na	Fe ₃ ³⁺	Al ₆	Si ₆ O ₁₈	(O) ₃	(OH)
	Fluor-olenite	Na	Al ₃	Al ₆	Si ₆ O ₁₈	(O) ₃	F
	Alkali subgroup 6	R ¹⁺	R ₃ ³⁺	R ₆ ³⁺	R ₃ ³⁺ R ₃ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Na-Al-Al-Al root name	Na	Al ₃	Al ₆	Al ₃ Si ₃ O ₁₈	(OH) ₃	(OH)
	Na-Al-Al-B root name	Na	Al ₃	Al ₆	B ₃ Si ₃ O ₁₈	(OH) ₃	(OH)
	Fluor-Na-Al- Al-Al root name	Na	Al ₃	Al ₆	Al ₃ Si ₃ O ₁₈	(OH) ₃	F
	Fluor-Na-Al- Al-B root name	Na	Al ₃	Al ₆	B ₃ Si ₃ O ₁₈	(OH) ₃	F
Calcic group	Calcic- subgroup 1	Ca ²⁺	R ₃ ²⁺	R ²⁺ R ₅ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Fluor-uvite	Ca	Mg ₃	MgAl ₅	Si ₆ O ₁₈	(OH) ₃	F
	Feruvite	Ca	Fe ₃ ²⁺	MgAl ₅	Si ₆ O ₁₈	(OH) ₃	(OH)
	Uvite	Ca	Mg ₃	MgAl ₅	Si ₆ O ₁₈	(OH) ₃	(OH)
	Fluor-feruvite	Ca	Fe ₃	MgAl ₅	Si ₆ O ₁₈	(OH) ₃	F
	Adachiite	Ca	Fe ₃	Al ₆	Si ₅ AlO ₁₈	(OH) ₃	(OH)
	Calcic- subgroup 2	Ca ²⁺	R ₂ ¹⁺ R ₁ ³⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Fluor- liddicoatite	Ca	Li ₂ ¹⁺ Al ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	F
	Liddicoatite	Ca	Li ₂ ¹⁺ Al ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Calcic- subgroup 3	Ca ²⁺	R ₃ ²⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ²⁻
	Ca-Mg-O root name	Ca	Mg ³	Al ₆	Si ₆ O ₁₈	(OH) ₃	O
	Lucchesiite	Ca	Fe ₃ ²⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	O
	Calcic- subgroup 4	Ca ²⁺	R _{1.5} ¹⁺ R _{1.5} ³⁺	Al ₆	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ²⁻
	Ca-Li-O root name	Ca	Li _{1.5} Al _{1.5}	Al ₆	Si ₆ O ₁₈	(OH) ₃	O
Vacant group	Vacant- subgroup 1	Vacancy (□)	R ₂ ²⁺ R ³⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Foitite	Vacancy (□)	Fe ₂ ²⁺ Al	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Magnesio- foitite	Vacancy (□)	Mg ₂ Al	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Vacant- subgroup 2	Vacancy (□)	R ₁ ¹⁺ R ₂ ³⁺	R ₆ ³⁺	Si ₆ O ₁₈	S ₃ ¹⁻	S ¹⁻
	Rossmannite	Vacancy (□)	Li ¹⁺ Al ₂ ³⁺	Al ₆	Si ₆ O ₁₈	(OH) ₃	(OH)
	Vacant- subgroup 3	Vacancy (□)	R ₁ ²⁺ R ₂ ³⁺	R ₆ ³⁺	R ₆ ⁴⁺ O ₁₈	S ₃ ¹⁻	S ²⁻

General formula	(X)		(Y ₃)	(Z ₆)	T ₆ O ₁₈	V ₃	W
□-Mg-O root name	Vacancy (□)	MgAl ₂	Al ₆	Si ₆ O ₁₈	(OH) ₃	O	
□-Fe-O root name	Vacancy (□)	Fe ²⁺ Al ₂	Al ₆	Si ₆ O ₁₈	(OH) ₃	O	
Vacant-subgroup 4	Vacancy (□)	R _{0.5} ¹⁺ R _{2.5} ³⁺	R ₆ ³⁺	Si ₆ O ₁₈	S ₃ ¹⁻	S ²⁻	
□-Li-O root name	Vacancy (□)	Li _{0.5} Al _{2.5}	Al ₆	Si ₆ O ₁₈	(OH) ₃	O	

Tourmaline has a general structural formula $XY_3Z_6(T_6O_{18})(BO_3)_3V_3W$, with the X, Y, Z, T, V and W sites all capable of varying degrees of chemical substitution (Table 2.2). Each site can incorporate different cations and anions (and multiple valences of the same cation). As a cyclosilicate, tourmaline's structure is characterized by a six-membered ring of tetrahedra. The tetrahedra's apical oxygens point toward the analogous (-c) pole (Barton 1969, Henry and Dutrow 1992).

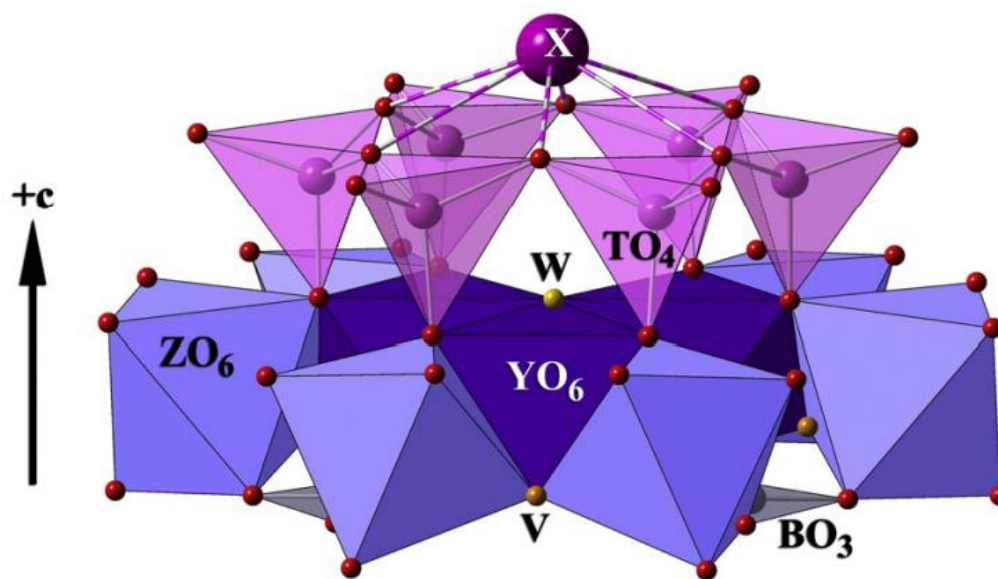


Figure 2.1 – Crystal structure of tourmaline, viewed perpendicular to the c-axis, with the sites labeled (Henry and Dutrow 2011.)

Table 2.2 – Site occupation in tourmaline, after Henry et al. (2011). Cations are denoted with an R, anions with an S. Cations and anions are presented in order of their relative abundances.

Site	Relative abundance of ions with different valence states	Common cations (R) and anions (S) in order of relative abundance
X	$R^{1+} > R^{2+} > \square$ (vacancy)	R^{1+} : $Na^{1+} >> K^{1+}$ R^{2+} : Ca^{2+}
Y	$R^{2+} > R^{3+} > R^{1+} > R^{4+}$	R^{2+} : $Fe^{2+} \sim Mg^{2+} > Mn^{2+} >>> Zn^{2+}$, Ni^{2+} , Co^{2+} , Cu^{2+} R^{3+} : $Al^{3+} >> Fe^{3+} > Cr^{3+} >> V^{3+}$ R^{1+} : Li^{1+} R^{4+} : Ti^{4+}
Z	$R^{3+} >> R^{2+}$	R^{3+} : $Al^{3+} >> Fe^{3+} > Cr^{3+} > V^{3+}$ R^{2+} : $Mg^{2+} > Fe^{2+}$
T	$R^{4+} >> R^{3+}$	R^{4+} : Si^{4+} R^{3+} : $Al^{3+} > B^{3+}$
B	R^{3+}	R^{3+} : B^{3+}
V	$S^{1-} >> S^{2-}$	S^{1-} : OH^{1-} S^{2-} : O^{2-}
W	$S^{1-} \sim S^{2-}$	S^{1-} : $OH^{1-} \sim F^{1-}$ S^{2-} : O^{2-}

The nine-coordinated X site is the largest site, able to accommodate large cations (commonly Na^{+} and Ca^{2+} , with some minor K^{+} or NH_4^{+} or remain vacant (Henry and Dutrow 1996, Henry and Dutrow 2011, Wunder et al.. 2015). The occupant of the X site forms the basis for the initial discrimination between primary groups of tourmaline, and thus the root name of the tourmaline species, e.g., schorl (Henry et al. 2011). Depending on what is present in the X site, compensation involving coupled substitution with ions in other sites may be required (Hawthorne and Henry 1999, Henry and Dutrow 2011).

The octahedral Y site has the greatest variation in cations: Mg^{2+} , Al^{3+} , Mn^{2+} , Fe^{2+} , Fe^{3+} , Cr^{3+} , V^{3+} , and Ti^{4+} as well as many other elements at trace amounts. Li^{1+} occurs in this site typically associated with a coupled substitution with Al^{3+} (Henry and Dutrow 1992). There seems to be little or no vacancy at the Y site (Hawthorne et al.. 1993). Trivalent cations dominate

the small, often-distorted Z octahedral site: Al^{3+} , Fe^{3+} , Cr^{3+} and V^{3+} . However, up to two apfu Mg^{2+} and, possibly, small amounts of Fe^{2+} can be found in this site (see Table 2.2, Henry and Dutrow 1992, Henry et al. 2011). The T site is predominantly occupied by Si^{4+} , with some substitutions by Al^{3+} and B^{3+} (Schreyer 2000, Marler et al. 2002). This is the only location in the structure that can be occupied by Si^{4+} , although Al^{3+} and B^{3+} can occupy other sites.

The three-coordinated BO_3 groups oriented perpendicular to the c-axis are exclusively occupied by B. There is some evidence for tetrahedrally-coordinated boron in both synthetic and natural tourmalines (e.g., Hughes et al. 2000, Ertl et al. 2008). The growth of tourmaline is strongly dependent on the availability of boron in the system.

There are 31 anions in the structural formula of tourmaline; these are present at eight distinct sites in the apices of coordination polyhedra, labeled O(1)- O(8) (Donnay and Buerger 1950). The O(1) and O(4)-O(8) sites contain only O^{2-} (Henry and Dutrow 1992, Hawthorne and Henry 1999 and references therein).

The W [O(1)] site can accommodate three different anions: OH^{1-} , F^{1-} , and O^{2-} . The different charges on the ions require coupled substitutions in the structure, such that if $\text{O}^{2-} > \text{OH}^{1-} + \text{F}^{1-}$, which would require the oxy species, a coupled substitution must take place in response to the difference in charge, limiting the potential occupants. The V site [O(3)] can contain OH^{1-} or O^{2-} , but is mostly dominated by OH^{1-} .

Tourmaline physical and petrologic background

Tourmaline occurs in igneous, metamorphic and sedimentary environments and supports its unique properties as a provenance indicator mineral (e.g. Van Hinsberg et al. 2011b).

Tourmaline has a large stability range (Figure 2.2). It does not form at surface conditions (25°C, 1 atm), but it is stable at temperatures and pressures found in diagenetic environments (150°C, 100 MPa). Upper pressure and temperature limits of stability of tourmaline depend on composition but generally are between 5-7 GPa and 725°C-950°C, respectively (Van Hinsberg et al. 2011a). Tourmaline is also stable in acidic to neutral pH values (Henry and Dutrow 1996) and is not stable in alkaline fluid compositions (Morgan and London 1989). Tourmaline's resistance to mechanical abrasion is comparable with corundum, rutile and zircon (Morton and Hallsworth 1999 and references therein.)

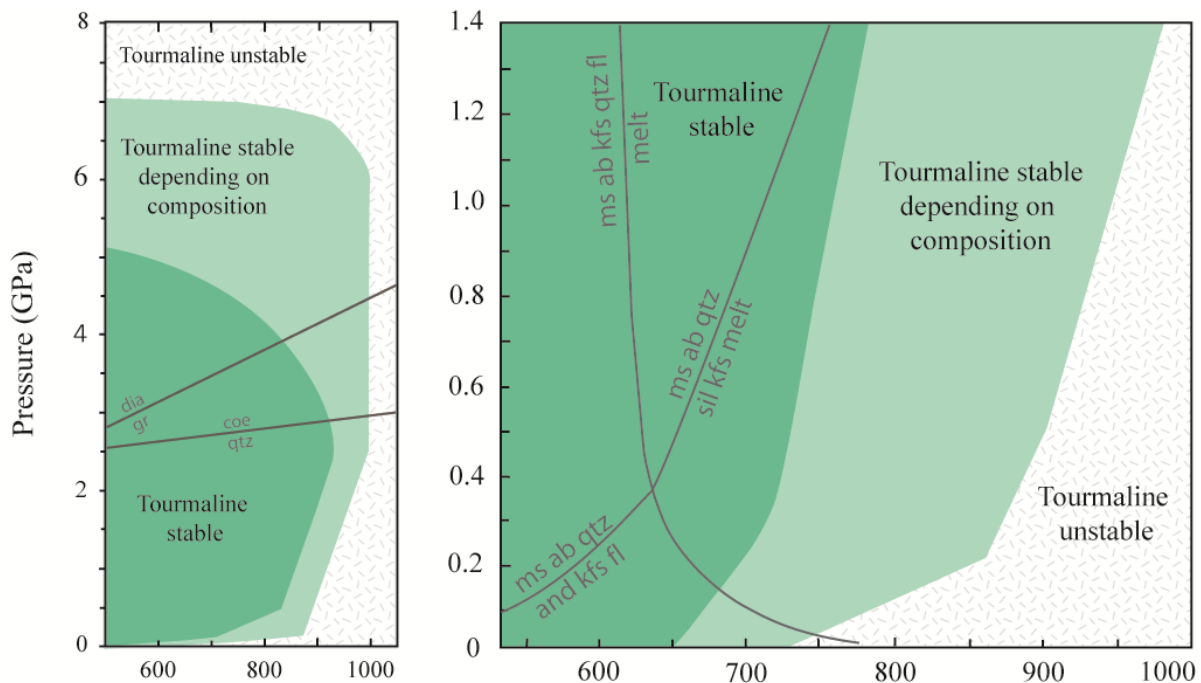


Figure 2.2 – Simplified stability field of tourmaline of various compositions from Dutrow and Henry (2011).

Under most crustal conditions, if boron is available from an internal or external source, tourmaline will generally develop. Tourmaline crystals grow faster at the antilogous (+c) end than the analogous end (-c) in lower temperature environments. At lower temperatures the pyramidal faces at either pole as well as the prismatic faces differentially incorporate certain cations, anions and isotopes and can produce sector zoning (e.g., Henry and Dutrow 1996, Van Hinsberg and Schumacher 2007). The preferential fractionation diminishes as temperature increases (Henry and Dutrow 1996). Rates of diffusion of cations and anions in the tourmaline structure are negligible; as such identifiable differences in composition in chemical zoning are preserved to the highest grades of metamorphism (e.g., Van Hinsberg and Marschall 2007, Van Hinsberg and Schumacher 2007.) The ready accommodation of so many different ions in the petrologic environment means that tourmaline can act as a recorder of the conditions in which it forms, a kind of ‘geologic DVD’ that records and preserves information (Dutrow and Henry 2011, Van Hinsberg et al. 2011a, Henry and Dutrow 2012, Dutrow and Henry 2016). Sector zoning of tourmaline is a source of information on thermometric conditions of formation (e.g., Van Hinsberg and Schumacher 2007), recording the changes of not just fluid composition but local temperature as well.

Provenance

Provenance studies can reveal the lithologies from a distal area (Krynine 1946), the tectonic history of the source area and, thus, the paleogeography, providing invaluable information for reconstruction of ancient terranes (Johnsson 1993) and provide criteria for correlation and differentiation of source units (Krynine 1946). Early elements of provenance studies were more qualitative than quantitative; for example, comparing the optical color of a tourmaline clastic grain with its suspected parent rock formation. Since the advent of widely

available microanalytical techniques, there has been a push to quantify provenance properties for standardized use across industry and research.

The use of heavy minerals (those minerals with a specific gravity higher than 2.80) as indicators of source lithologic units has a long history (e.g. Morton 1991). This includes common rock-forming minerals like pyroxenes, garnets and micas, and accessory minerals like zircon, apatite, rutile, and tourmaline. The proportion of these minerals in sands is a function of two separate sources of variation: mineral sources (lithologies) and transport sources. Variability and concentration of heavy minerals in sediments can be due to intrinsic mineral properties like specific gravity, durability and stability. Transport sources of variation in heavy mineral distribution include hydraulic sorting, sedimentary basin shape, transport distance and flow velocity; Morton and Hallsworth (1994) identified hydraulics and diagenesis as the most important controlling factors on developing and maintaining heavy mineral suites in sedimentary rocks. They noted that the mechanical behavior of grains in water was dependent on grain size and shape (which was in turn reflective of intrinsic mineral properties like habit and cleavage). Mineral species with properties that are similar will behave in similar ways hydraulically, so the physical mechanisms of transport will tend to concentrate minerals with like habits and densities in the same places within sediment storage. Authigenic and diagenetic processes further modify mineral assemblages in sandstones. Heavy minerals in provenance studies are susceptible to mechanical concentration, which can create unrealistic analogues for geologic units, and the recycling of heavy mineral grains into new sediment loads (and eventually into new units).

Heavy mineral ratios or provenance-sensitive index values compare amounts of chemically and mechanically resistant minerals with more unstable mineral species with the same hydraulic properties from the same rock type (Morton and Hallsworth 1994). Using heavy

mineral index values is not destructive and may be undertaken in the process of concentrating heavy mineral grains for microanalysis. Diagenesis has the “most profound” effect on heavy mineral suites, with some species lost entirely to dissolution; thus provenance-sensitive index values must contain one mineral that is resistant to dissolution or reaction at both surface temperatures and pressure, as well as abundant in detrital sediments. Examples of the provenance-sensitive indices include garnet-zircon (GZi) and apatite-tourmaline (ATi), which compare the amount of remaining garnet to zircon and apatite to tourmaline, respectively. Based on lateral or temporal changes in the ratios of these similar heavy minerals (index values), changes in provenance may then also be inferred (Morton and Hallsworth 1994).

The zircon-tourmaline-rutile (ZTR) maturity index was proposed by Hubert (1962) for use in sandstones as a measure of a sandstone’s mineralogical maturity and is the “percentage of the combined zircon, tourmaline, and rutile among the transparent, nonmicaceous detrital heavy minerals.” Mineralogical maturity can be an indicator of how long sediment has been in transport. Along with textural information about sorting, rounding, and authigenic overgrowths, maturity indices reflect the erosional and depositional history of a sediment.

Krynine (1946) examined the occurrence of the tourmaline group in sediments, including making inferences about provenance from tourmaline grain morphology, color, overgrowths and concentrations in sediments. In this work, he attempted to draw conclusions about the relationships between tourmaline color, morphology, and composition, as well as the relationship between these qualities and their likely environments of formation. He identified the following types of tourmalines: granitic tourmalines, pegmatitic tourmalines, metasomatic tourmalines that form as a consequence of fluid injection during regional pegmatite-related metamorphism, authigenic ‘cold water’ tourmalines that form on the sea bottom, and “non-injected bedrock” or

detrital tourmalines (which are in turn weathered out from the four ‘primary’ sources, and become incorporated into a younger sedimentary rock.) He included several photomicrographs of detrital tourmaline in plane-polarized light, pointing out the morphology of grains in different stages of transport, the shape of authigenic overgrowths, and the value of color as discriminants between several potential sedimentary provinces (see Suttner 1974).

Although some general correlations between color and tourmaline species exist, using color as an indicator of source material is problematic (Dietrich 1985). Tourmaline compositions (rather than color) provide a more meaningful basis for source rock discrimination. With the acquisition of large amounts of microanalytical data on tourmaline, the additional dimension of composition could be used to establish provenance with tourmaline. Henry and Guidotti (1985) demonstrated the usefulness of the chemistry of tourmaline as a petrogenetic indicator that could reveal information about source rocks. They used tourmaline analyses from sources in the literature to develop two ternary plots (Figures 2.3 and 2.4.) Recognizing the significant ranges of calcium, iron, magnesium, and aluminum found in tourmaline, they considered that these elements would provide the greatest discrimination among potential source rock types. To illustrate these variations they used two ternary diagrams: the $\text{Al}_{50}\text{Fe}(\text{tot})_{50}\text{-Al}_{50}\text{Mg}_{50}$, and $\text{Ca-Fe}(\text{total})\text{-Mg}$ ($\text{Ca-Fe}(\text{tot})\text{-Mg}$). Analyses with known provenance from the literature were used to define fields on these compositional diagrams. Chemical analyses from measurements were plotted on the diagrams and fell into one or more of these fields, yielding a suggested provenance for that composition. The strength of this approach is that it is an easy-to-understand AFM-style ternary diagram useful for provenance for a wide range of rock types. However, this approach only considers four of the many possible cations that are present in the tourmaline, potentially limiting our understanding. There are several multivariate statistical methods that could be

potentially be used for classification, some of which have already been used in geology for classification, e.g., Griffin et al. 1997. Weltje (2002) recommends referring to a geological “sample” as a specimen, to avoid confusion with the similar statistical term.

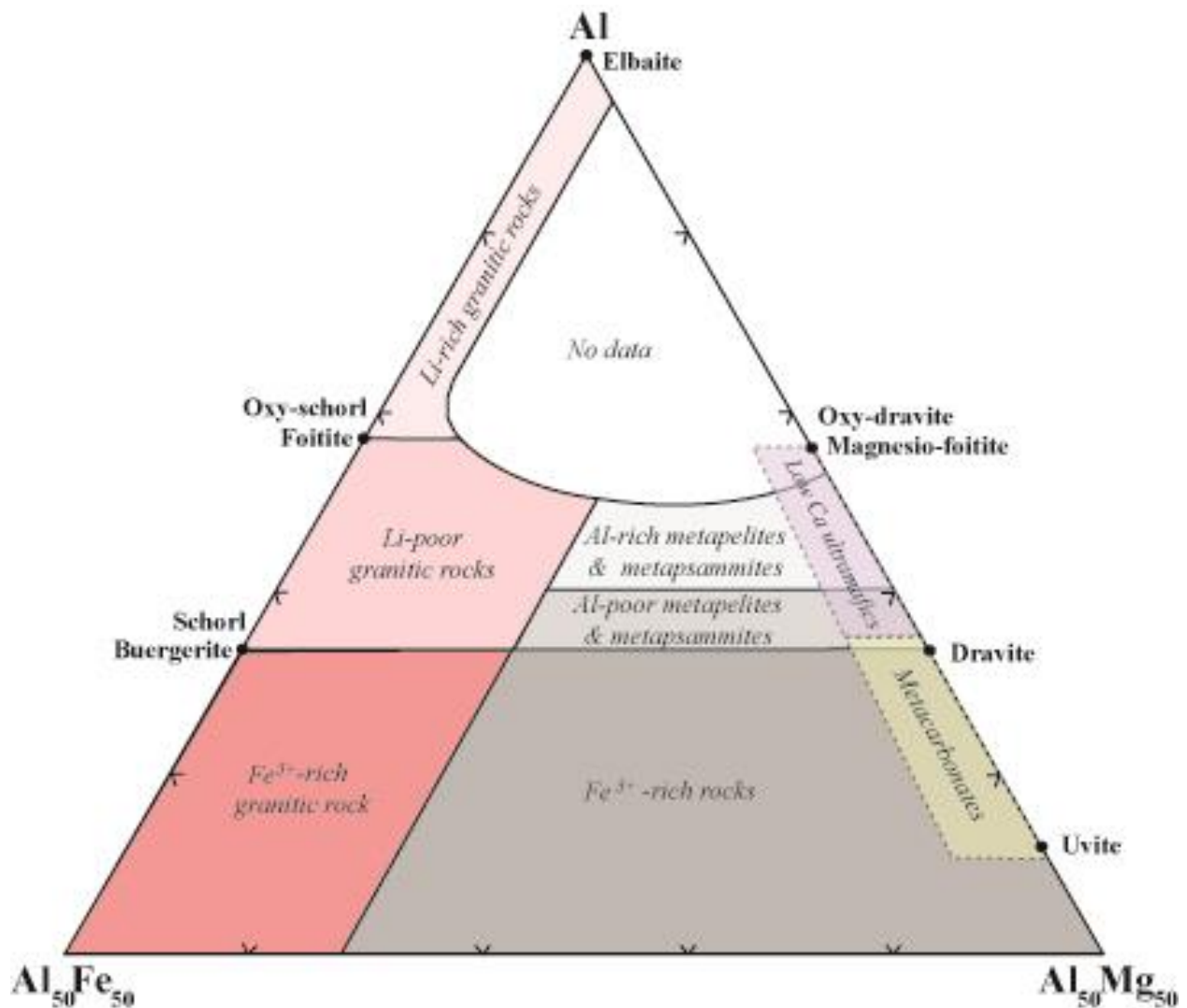


Figure 2.3 – AFM ternary diagram (in molecular proportions) for provenance discrimination, after Henry and Guidotti (1985) and Van Hinsberg et al. (2011b). Fe is considered as the sum of Fe^{2+} and Fe^{3+} . Major tourmaline species are plotted as a guide. Note that the fields associated with low-Ca metaultramafics and Cr, V-rich metasediments (the purple field) and metacarbonates and meta-pyroxenites (the yellow field) overlap the fields associated with metapelites and Fe^{3+} -rich rocks.

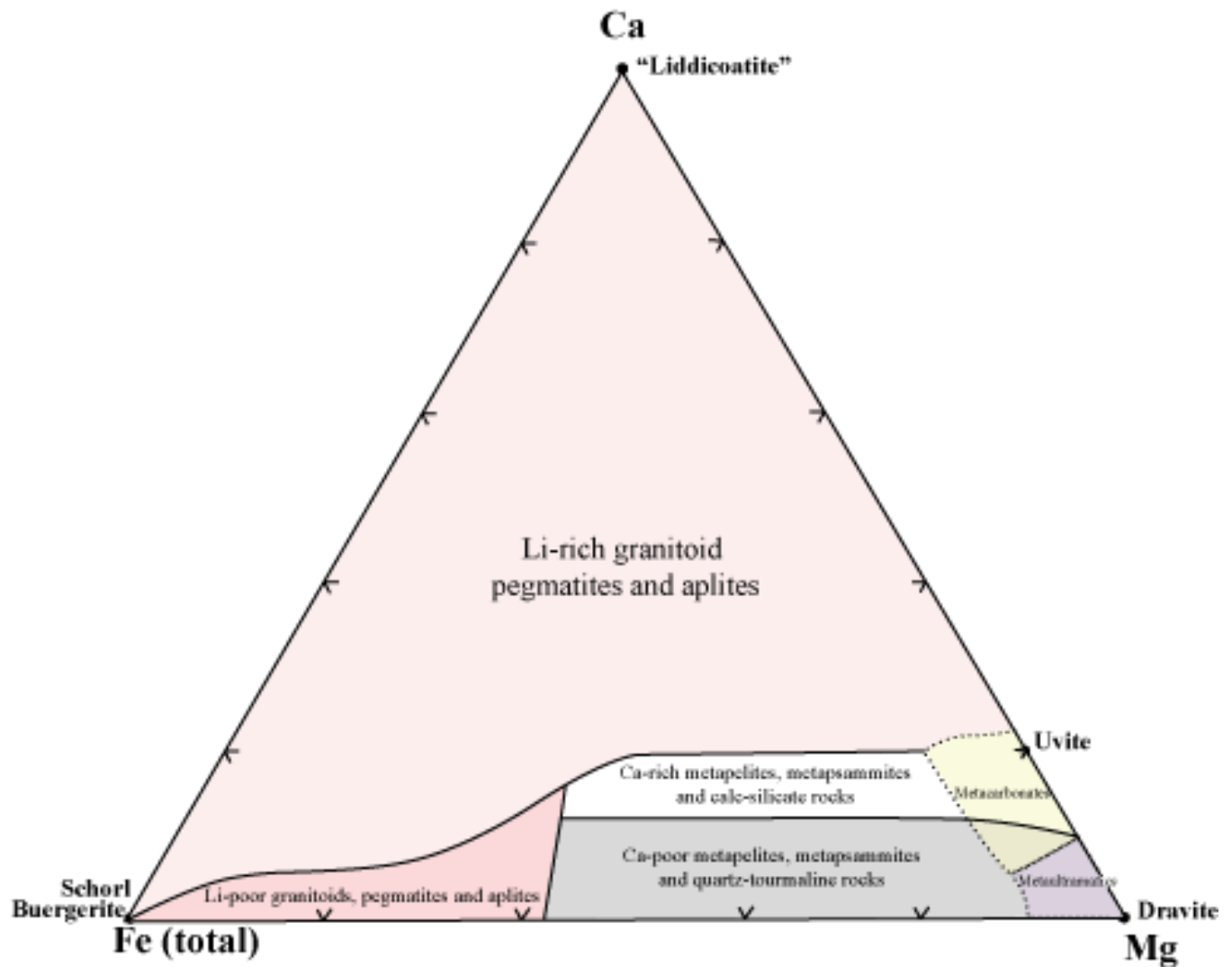


Figure 2.4 – Ca-Fe(tot)-M ternary diagram (in molecular proportions) for provenance discrimination, after Henry and Guidotti (1985). Major tourmaline species are plotted as a guide. The fields correspond to (1) Li-rich granitoid pegmatites and aplites, (2) Li-poor granitoids and associated pegmatites and aplites, (3) Ca-rich metapelites, metapsammites, and calc-silicate rocks, (4) Ca-poor metapelites, metapsammites, and quartz-tourmaline rocks, (5) Metacarbonates, and (6) Metaultramafics. Note that fields 5 and 6 overlap with fields 3 and 4, respectively.

CHAPTER 3 - STATISTICAL BACKGROUND

Random forests

There are numerous statistical methods available to evaluate chemical data. Classification trees are robust, easy to understand and do not require a lot of computational resources.

Conceptually, an analysis is placed at the “trunk” of a tree and at branching points, moves distally, until it is in its own class with others that are very similar (a terminal node, or “leaf”).

One classification tree gives one expected classification outcome for each specimen.

Unfortunately, with a single decision tree, one decision is made about the classification outcome, and the discriminatory power of more sensitive classifiers may be lost. Important variables may be missed or narrowly outperformed at decision splits.

Ensemble learning builds prediction models by “combining the strengths of a collection of simpler base models” (Hastie et al. 2009). Ensemble methods reduce over-fitting by averaging the result of multiple models to produce an outcome; multiple diverse models that are averaged together or otherwise collected can obtain better results than a method that only uses one model (Dietterich 2000). Classification trees are vulnerable to being over-complex (for example, one analysis per terminal node instead of multiple analyses contained in a node) and become more computationally resource-intensive as added variables make the ‘best tree’ unfeasible to calculate. Pruning a classification tree using a greedy algorithm, which makes the best possible decision at a decision switch, is one way to reduce the complexity of trees. Minimal cost-complexity pruning using the mean square error keeps the largest amount of data in the tree possible to avoid loss of resolution and information on interactions between classifiers, while maximizing correct predictions.

Caruana and Niculescu-Mizil (2006) tested multiple supervised learning methods, and suggested bagged trees, random forests and neural nets as the best methods for classification. Decision trees are able to capture complex interactions between variables but have a tendency to overfit the data, especially in the presence of noise in the data set; this is the tendency of classification trees to produce classifiers with low bias but high variance (a familiar feature of the bias-variance tradeoff). To reduce variance between models (and therefore improve classification results from more than one tree which may split on different variables), averaging together multiple outcomes from trees that are all grown to the same depth can lower variance without increasing bias (Hastie et al. 2009). One method to do this is called bagging, from ‘bootstrap aggregating’ and was proposed by Leo Breiman (1996).

Bootstraps test the distribution of data by using randomly selected portions of that data with replacement. The bootstrap method divides a set of data with n samples into a training set, T and a learning set, L , by randomly sampling the data set. Each time a bootstrap sample B is obtained from that data set, the entire data set is reloaded for random selection in the next sampling run, up to n times. Over many sampling runs, a single piece of data may be selected for inclusion in a bootstrap more than once. For sufficiently large data sets ($n > 50$), a bootstrap sample’s composition approaches 63.2% of the original data set, and is labeled with the correct dependent or output value, y , forming training set T . The remaining 36.8% of the original data set is left out of the training set and forms the learning set L . The bootstrap sample replicates the behavior of the original data set, so fitting the model to the bootstrap data set produces classifiers with the same characteristics and behavior of the original data set. To aggregate the bootstrap samples, a predictor function $Q(x, T)$ is used to construct classifiers from the original data set using bootstrap sampling, such that the k th predictor is based on the k th bootstrap training set

(Breiman 1996b). Bootstrap aggregating is often done on classifiers, especially decision trees; growing multiple trees and averaging the results (aggregating) will combine the strengths of decision trees with the ‘wisdom of crowds’. An additional feature of bagging was the development of the ‘out-of-bag’ (OOB) measurement, which determines the rate at which the OOB samples (which formed the learning set L) are misclassified and is comparable to the actual misclassification rate (Tibshirani 1996, Breiman 2001.) Bylander and Hanzlik (1999) and references therein state that OOB estimates of classification error are more ‘pessimistic’ than true error rates. Using OOB error rates will allow for a more conservative evaluation of a constructed forest, as true misclassification error rates will likely be lower.

However, including a random perturbation of the system was posited by Ho (1998) to improve accuracy of classification in decision forests and was further expanded upon by Breiman (1998), who determined that the random sampling in bagging would be a sufficient source of randomness (Denil et al. 2014). Revisions of the method also introduced the random selection of a feature on which to split the tree, to keep the construction of trees diverse. Random forests, which grows hundreds of trees using a random subset of the data in each tree and averages the result, was determined to be the best approach for handling tourmaline provenance data, because it keeps the largest amount of data in the trees until the voting process, allowing the capture of potentially unknown interactions between chemical elements.

Random forests (RF) is a combination of decision trees and bagging (Figure 3.1), developed by Leo Breiman and Adele Cutler in 2001 (please see Breiman 2001 for proofs). While Random Forests has been trademarked and is offered as part of a proprietary software package distributed by Adele Cutler, other researchers have continued to develop and refine the random forests algorithms. Some have developed software packages that are open-source and

free to use; one such package is available for the free statistical computer software R (<http://www.r-project.org>) and maintained by Andy Liaw (Liaw and Wiener 2002). To prevent confusion between them, the trademarked software package will be denoted (Random Forests) and the R software package as (randomForest). RF or random forests is intended to refer to the statistical technique itself and not the trademarked software package or the package for R.

RF is a nonparametric, supervised ensemble method. It has been used in multiple branches of social and medical sciences because of its ability to handle data with high dimensionality. This data may be homogenous or heterogeneous, and has the potential to accommodate information like petrographic textures, mineral facies or associations, and metamorphic grades in addition to ‘real-number’ raw measurements of chemical compositions, isotopic ratios, or data from Raman or Mossbauer spectroscopy.

RF will rank each variable by importance in making predictions of classification; knowing which chemical elements are the most important helps us understand how the tree is splitting and what other factors might be influencing the splits. This variable importance measurement is also useful in model reduction. It may be that some chemical elements are noise predictors and can be eliminated in favor of producing a model that is simpler, while still being accurate. RF becomes more accurate with large numbers of classifiers, although a point of diminishing returns is reached at $n = 500$ classification trees. Accuracy is also increased by the use of a training set and test set that are separate. Using unlabeled “never before seen” data reduces overfitting in the trees (Hastie et al. 2009.) Random forests are well-suited to the volume and complexity of tourmaline chemical data and are capable of accurately identifying distinct chemical sources of tourmaline with a low misclassification rate.

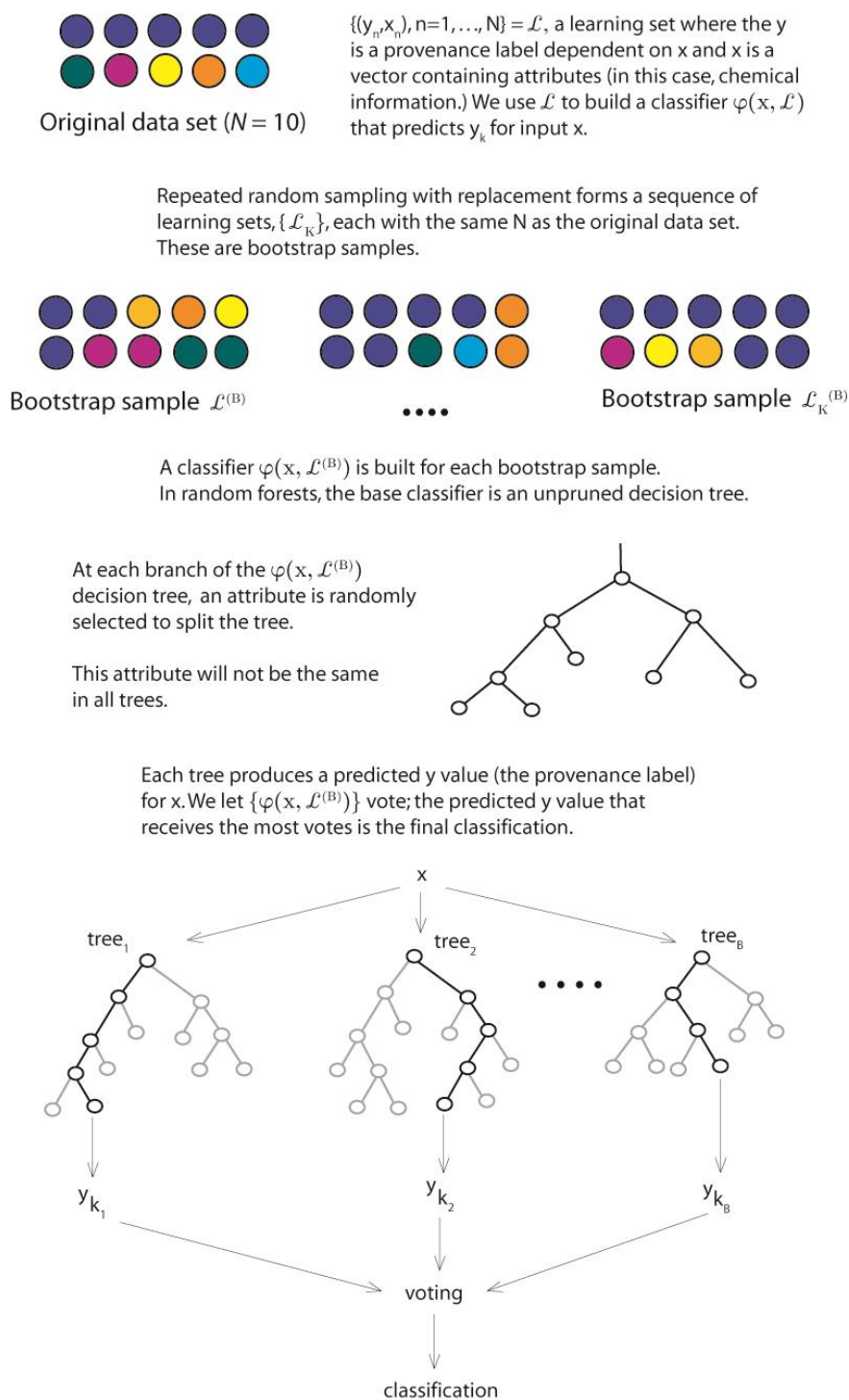


Figure 3.1 – A diagram showing how random forests are constructed from bootstrap aggregated decision trees. The different colors of the samples in the original data set represent different types of tourmalines. Sampling from the original data set N may lead to some kinds of tourmalines not being included in each bootstrap. Parts of this diagram were taken from Verikas et al. 2011.

Challenges to using random forests include the lack of a model; the forest is newly grown every time the code is loaded, and code must be included to retain a specific forest for future use. Newly growing a forest each time may also change variable important measurements between features that are narrowly competing for the greatest importance.

Statistical analytical approaches to provenance studies

Statistical approaches specifically hold a great deal of power to manage high-dimensional data like mineral chemical analyses (e.g. Belousova et al. 2002a). Random forests have been used in addressing problems in medicine, life sciences, and the social sciences, but they have also been used in forestry (Attarchi and Gloaguen 2014), soil science (Pahlavan Rad et al. 2014), mapping (Shruthi et al. 2014), hydrology and aquifer management (Baudron et al. 2013), and ore grading and exploration (O'Brien et al. 2015, Sheng et al. 2015).

Baudron et al. (2013) used random forests as a method to classify and then identify natural waters from an aquifer system in Spain. The authors wanted to determine the origin of well water samples in a complex aquifer system, using widely available measurements of major aqueous chemical constituents. Several statistical methods were tested, including linear discriminant analysis (LDA) and classification and regression trees (CART). LDA was able to classify groundwater samples with 84% accuracy; CART was able to achieve 88% accuracy. Using random forests resulted in a model that classified groundwater origins with 94.3% accuracy.

Clarke et al. (1989) began developing tourmaline as an indicator mineral for economically viable deposits in Nova Scotia, Canada; the data they used included chemical information as well as boron isotopes. Using both LDA and quadratic discriminant analysis

(QDA), the authors were able to distinguish between three different populations of tourmalines defined as barren, granite-related mineralized deposits, and non-granite-related mineralized deposits with up to 89% accuracy using LDA and 98% accuracy using QDA. Belousova et al. (2002a, b) used classification and regression trees on trace element compositions of apatite and zircon to determine source rock composition. Using predictions generated by these methods, the authors recommended the adoption of a statistical method that could identify a tourmaline's source rock for economic purposes.

The literature has a large body of tourmaline chemical data with known provenance which can be used to develop a database of samples to serve as a starting point for differentiating between source rock types. Using random forests, information about tourmaline chemical composition develops a set of “rules” for the classification of tourmalines according to source rock type. Further development of the method follows the workflow shown in Figure 3.2.

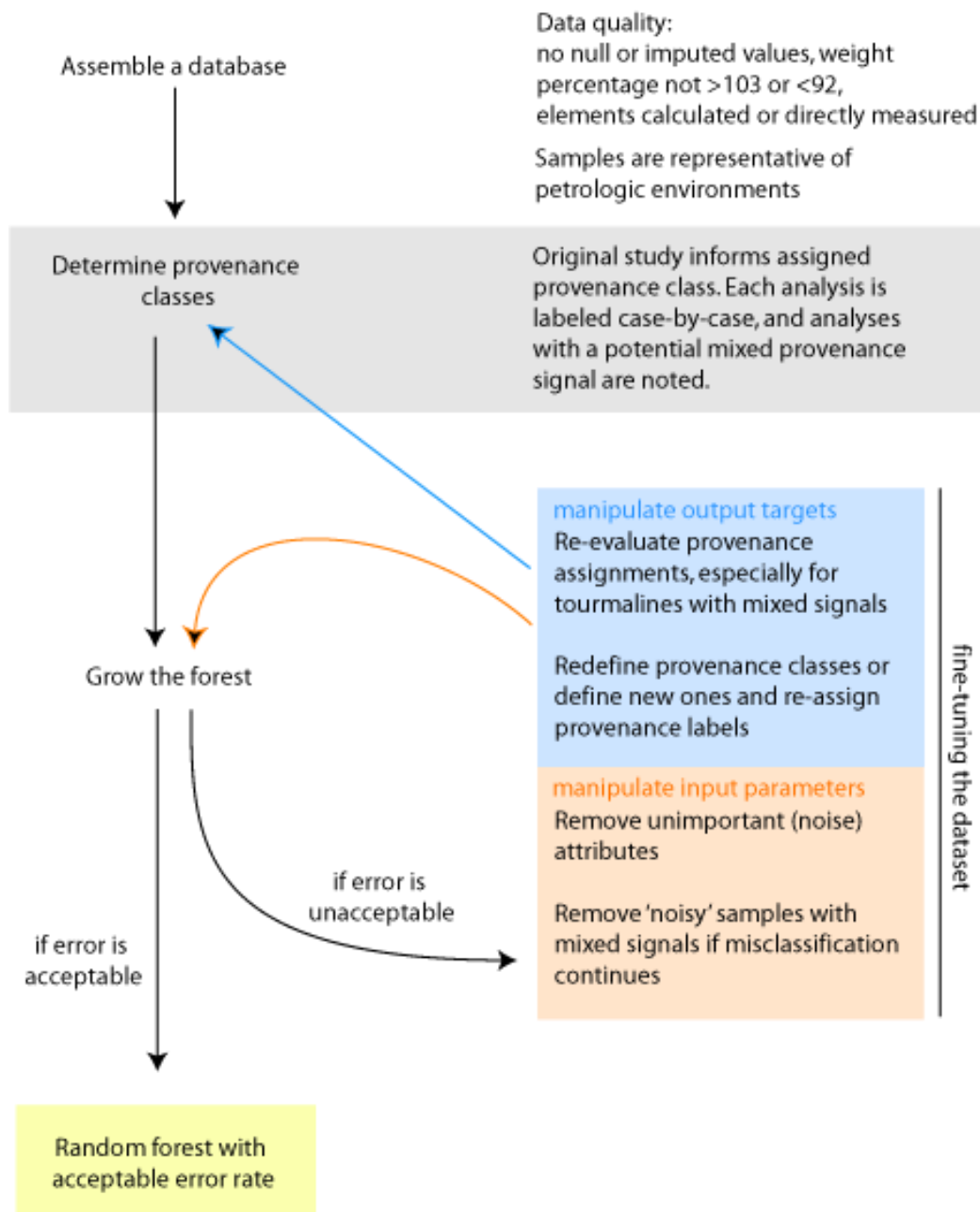


Figure 3.2 – Iterative workflow method for this study, developing tourmaline data set and associated random forests. Fine-tuning methods as suggested by Dietterich (2000).

CHAPTER 4 – INPUT DATA AND PROGRAMMING ENVIRONMENT

Tourmaline input data for statistical modeling

Tourmaline chemical data are used with the random forest method to obtain a statistical model for provenance applications. The input used for the random forest method is tourmaline mineral-chemical data coupled with its known provenance. Although any tourmaline parameter can be used (e.g., color, shape, etc.) for this type of statistical analysis, mineral chemistry is considered the most useful. A relatively comprehensive list of 39 potential tourmaline source lithologies was developed by Darrell Henry (personal communication) and serves as a starting point for establishing possible provenance classes for this statistical model (see Table 4.1). The input data used for this modeling is derived from the literature (see Appendix B for literature descriptions). Assignment of a specific tourmaline to a specific lithologic environment can be challenging because of several factors that can obfuscate the lithologic assignment including: a mixed chemical signal from host rock and infiltrating fluid, strong zoning in the tourmaline, and diagenetic and metamorphic overgrowths on detrital tourmaline cores. For each sample, its field location was noted from its respective study and used to assign a provenance class.

Tourmaline mineral chemistry has been typically determined using two different analytical approaches—wet chemistry and electron microprobe analysis (EPMA). Wet chemical analytical techniques allow all elements and the oxidation states of transition elements to be determined. However, this approach is time-consuming and uses entire grains so that any chemical zoning is lost. In contrast, analysis using the EPMA can determine tourmaline compositions at the micrometer scale, but there are analytical limitations that must be considered. One of the most important tourmaline constituents, boron, is not analyzed very accurately with EPMA and boron is commonly assumed to be 3 B apfu (Henry et al., 2011).

Other light elements such as hydrogen and lithium cannot be analyzed and the oxidation states of transition elements cannot be directly evaluated with an EPMA, but there are methods to approximate these elements (e.g., Henry and Dutrow 1996, Henry et al. 2011). Nonetheless, light elements are more frequently being analyzed at the micrometer scale using techniques such as SIMS; these data can be used to check the estimation procedures of light elements and varying oxidation states obtained from the EPMA microanalyses.

Both analytical techniques typically report the compositions of the elements analyzed in terms of weight percent (wt%) oxide, with the exception of the anions F and Cl. To calculate a structural formula of a mineral, these wt% oxide data are normalized based on an assumed number of anions in the structural formula (e.g., 31 oxygens) or a fixed number of cations (e.g., Si=6). Next, the calculated ions are distributed into tourmaline structural sites based on several assumptions of the appropriate site occupancy (see Henry et al. 2011). There are potential issues in using normalized ionic values and structural-site assignments for specific ions as the input for the statistical models. In these cases analytical errors in one or more of the measured elements can propagate through all of the normalized ions and site-assigned ions, and this can skew the data. As such, in this study the measured wt% oxides (or element% F) are directly used as input for the statistical model without normalization. Because Li is a very important constituent of tourmaline in some granitic pegmatites, Li_2O is estimated with a procedure established by Pesquera et al. (2016) and used for the Li_2O value unless Li_2O is directly measured by wet chemistry or SIMS.

To generate random forests, all of the data can be used to create classifiers, but not all input parameters used to build classifiers are equally important. Parameters which are not important can be eliminated in the model without significantly changing the classification result

(Liaw and Wiener 2002). In tourmaline, a relatively comprehensive group of input parameters for the statistical model include the following chemical elements, (in wt% oxides and wt% F, Cl): B₂O₃, SiO₂, Al₂O₃, TiO₂, Cr₂O₃, Fe₂O₃, FeO, MnO, MgO, V₂O₃, ZnO, SrO, CaO, Li₂O, Na₂O, K₂O, F, Cl. In the case of EPMA data, Li₂O was estimated using the procedure of Pesquera et al. (2016). Because the EPMA cannot directly determine Fe₂O₃ contents, the Fe data are assumed to be all FeO. For those wet chemical analyses in which Fe₂O₃ was measured, the data was recalculated so that all of the Fe₂O₃ is recast as FeO.

For specific applications some of the unimportant input parameters (as determined by the random forest's variable importance measurement) can be eliminated, e.g. compared to F, Cl is not important in splitting the decision trees and was removed for some forests. In the case where there was missing data either the sample is not used or the parameter is assigned a zero for the purposes of modeling. As a way of filtering the inferior data, specimens with weight percentage totals lower than 92 or higher than 103 were not used. Divisions are made according to general rock type, important constituents like lithium or aluminum, and metamorphic grade. Rock types containing aluminum-saturated phases (e.g., andalusite, kyanite) are considered aluminum-rich. Rocks with lithium measurements higher than 40 ppm are considered to be enriched in lithium.

Table 4.1 – Potential source lithologies containing tourmaline (Darrell Henry, personal communication). This ideal classification scheme may not reflect actual provenance classes.

Class	General provenance	Lithologic or chemical type	Specific lithologic association or provenance
1	Granitic	Low Li	Aplite
2	Granitic	High Li	Aplite
3	Granitic	Low Li	Pegmatite
4	Granitic	High Li	Pegmatite
5	Granitic	Low Li	Plutonic
6	Granitic	High Li	Plutonic
7	Granitic gneiss	Low Li	Metamorphic
8	Granitic gneiss	High Li	Metamorphic
9	Metapelite	Diagenetic	Monopolar growth
10	Metapelite	Low Al	Low grade
11	Metapelite	High Al	Low grade
12	Metapelite	Low Al	Medium grade
13	Metapelite	High Al	Medium grade
14	Metapelite	Low Al	High grade
15	Metapelite	High Al	High grade
16	Metapsammite	Diagenetic	Monopolar growth
17	Metapsammite	Low Al	Low grade
18	Metapsammite	High Al	Low grade
19	Metapsammite	Low Al	Medium grade
20	Metapsammite	High Al	Medium grade
21	Metapsammite	Low Al	High grade
22	Metapsammite	High Al	High grade
23	Calcareous metasediment	Marble	Low grade, >50% carbonate
24	Calcareous metasediment	Marble	Medium grade, >50% carbonate
25	Calcareous metasediment	Marble	High grade, >50% carbonate
26	Calcareous metasediment	Calc-silicate rock	Low grade, <5% carbonate
27	Calcareous metasediment	Calc-silicate rock	Medium grade, <5% carbonate
28	Calcareous metasediment	Calc-silicate rock	High grade, <5% carbonate
29	Meta-mafics	Greenschist	
30	Meta-mafics	Amphibolite	
31	Meta-mafics	Mafic granulite	
32	Meta-mafics	Mafic eclogite	
33	Meta-mafics	Blueschist	
34	Meta-ultramafics		
35	Meta-evaporites		
36	Meta-ironstones		
37	Quartz veins	Barren	
38	Quartz veins	Sn-W deposits	
39	Tourmalinite		

The R environment

The randomForest package for R generates variable importance measurements for the features each time a forest is grown. Variability in the performance of the forest can be directly related to class definitions and how ‘correctly’ a sample is labeled. Liaw and Wiener (2002) indicate that although importance measurements may vary from run to run, the ranking of importance tends to be stable. Even though there is no model and the trees grown are different every time, the competition between attributes in the forest should produce similar results each time a forest is grown on a data set.

The output for randomForest includes the OOB rate as well as a confusion matrix and a ratio of correct to incorrect classifications given as ‘class.error’. The class.error value is the number of Type I and Type II errors summed and divided by the total number of specimens in the provenance class. Type I errors are ‘false positives’, a specimen assigned to a class when it does not belong to that class. Type II errors are ‘false negatives’, or the forest failing to assign a specimen the class to which it actually belongs. The confusion matrix allows performance of the forest to be evaluated easily and quickly: it is obvious which classes are underperforming, because their class.error values approach one (and those values for which accuracy would be low; conversely, when accuracy is high, class.error values approach zero). The package also includes a ‘predict’ function which generates a probability for any particular specimen to be put into each provenance class. Comparing labels with probabilities allowed determination of inaccurate assignment of provenance to a specimen.

Keeping in mind that the decision trees in the forest are weak learners (Schapire 1990), probabilities were compared for each specimen’s final classification with the known provenance labels. Most individual specimens showed high probability for a single class, but a few

generated high or nearly equal probabilities in multiple classes. Taken together with the false positives (in class.error) from the randomForest output, the focus was on labeling specimens to reduce misclassifications and reduce false positives.

The confusion matrix (Figure 4.2) used in forest development works only with labeled samples for which the provenance is already known; for samples with unknown provenance, a different function of the package is used. The ‘predict’ function may return both a table of probabilities and a ‘response’ (classification) value. The response value uses the existing trained forest to classify new (unknown) tourmaline specimens. The probability value returns a table of probabilities for each specimen and class, i.e., how well each specimen fits into a class (See Appendix B for example output). The ‘predict’ function’s response value is the predicted classification for an unknown specimen.

```
> print(fit.rf)

Call:
randomForest(x = X.matrix[train., ], y = factor(Y.Class[train.]), ntree = 500, importance = T, proximity = T)
Type of random forest: classification
Number of trees: 500
No. of variables tried at each split: 3

OOB estimate of error rate: 6.46%
Confusion matrix:
  1  2  3  4  5  6  7  8 class.error
1 74  2  3  0  0  4  0  3 0.13953488
2  2 383  4  0  0  1  0  0 0.01794872
3  1  2 95  0  0  0  0  0 0.03061224
4  0  0  0 183  1  1  0  7 0.04687500
5  0  0  0  2 16  3  0  1 0.27272727
6  5  0  0  1  0 53  0  1 0.11666667
7  0  0  0  4  0 20  0  0 0.23076923
8  4  0  1  8  1  0  0 102 0.12068966
> round(imp[,ncol(imp)],d=3) #use the MeanDecreaseGini as measure of importance
  Al2O3  TiO2  FeO  MnO  MgO  CaO  Li2O  Na2O  F
90.946 37.476 83.323 78.515 142.341 96.240 89.369 51.533 91.431
>
```

Figure 4.2 – Example output (Forest J) from the randomForest package in R. The OOB estimate of the error rate is 6.46%, and the confusion matrix is included. Columns are actual provenance class labels and rows are provenance predictions; any entries not in the diagonal are misclassifications. Eight specimens were labeled as Class 4 – Metapelites and metapsammites but the forest predicted they were Class 8 – Hydrothermal. These misclassifications are likely a result of the tourmaline specimen containing provenance signals from more than one source, in this case, a hydrothermal tourmaline ‘looks’ more like a metapelite/metapsammite tourmaline.

CHAPTER 5 – RESULTS

The statistical modeling for provenance data is done in three stages: (1) a test using tourmaline data from a limited set of lithologies, (2) generation of a random forest incorporating a large tourmaline data set from a variety of host lithologies and (3) application of the forest to a set of independent tourmaline data with a known source.

Test with limited numbers of lithologies

Pilot testing used a small database of 275 tourmaline analyses representing tourmaline from compositionally distinct lithologies: (1) Li-rich granitic pegmatite, (2) calcareous metasediment and (3) evaporite. Bloomfield (1997) generated EPMA analyses of gem tourmaline from the Sahatany Valley, Madagascar from a lithium-rich granitic pegmatite (1) that cross-cuts metacalcareous country rocks. This study also included analyses of tourmalines crystallized exclusively from the metacalcareous country rocks (2). A third lithologic type are tourmalines developed in evaporates (3) found in the cap rock of a salt dome in the Gulf of Mexico (Henry et al. 1999).

Using the randomForest statistical package, a forest was grown on this data that could discriminate between these three populations with a 3% OOB rate (i.e. misclassification rate), [which is excellent performance for a data-mining technique and is statistically significant.] Information about the similarity of data and variable importance were also obtained from this test run and are presented in Figure 5.1. Data that are more similar to each other cluster more tightly together (Liaw and Wiener 2002), so visual clustering indicates different groups of tourmalines. Although determining which population is which is unnecessary, three groups are readily observable; those that did not cluster tightly with the other groups are likely tourmalines with a

mixed chemical signal. Based on this limited dataset, the randomForest package can distinguish among these three lithologies in a very robust manner.

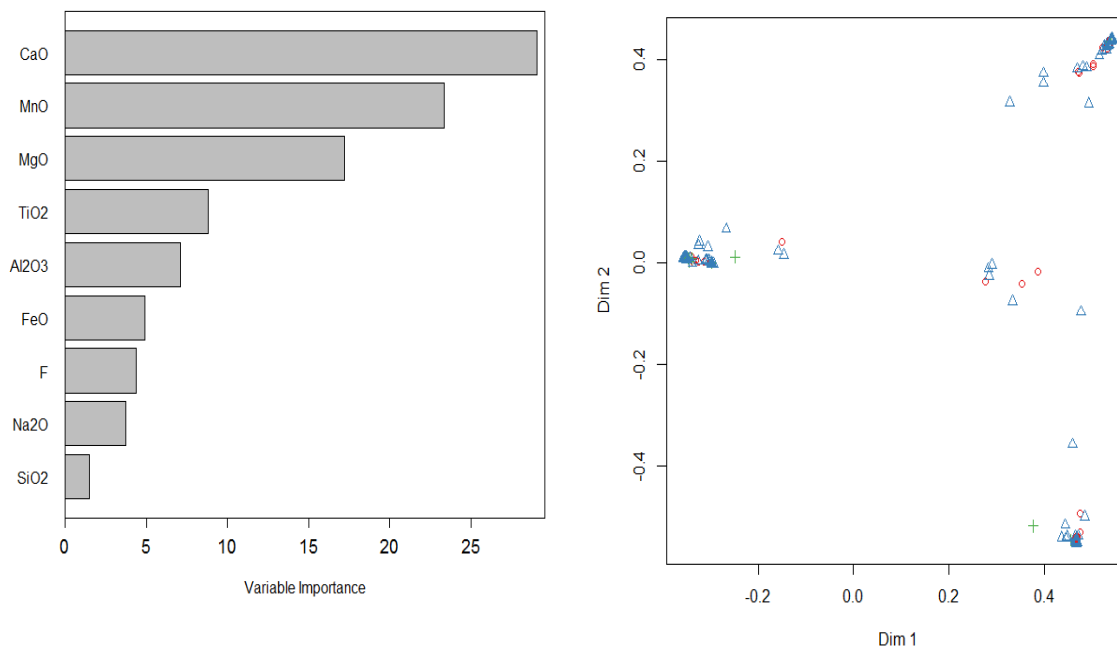


Figure 5.1: Forest growth with the randomForest function using 275 analyses from 3 lithologies for the test data set. The bar graph on the left shows ranking of chemical elements in tourmaline in order of importance, as determined by the program's variable importance function using the mean decrease of the Gini index (Liaw and Wiener 2002). The plot on the right is a multidimensional scaling (MDS) proximity plot, showing the proximity of data sorted by the program. The axes are dimensionless.

Generation of random forests incorporating large tourmaline datasets

Based on the success of this method on the test data, a database was assembled out of data from 65 different sources in the literature using representative samples of tourmaline analyses with different provenance and environments of formation (Darrell Henry, personal communication). 6019 specimens (analyses) were labeled with one of 39 provenance classes and were used to grow a forest. The forest grown from this data had a 29.4% OOB error rate,

indicating that samples were correctly classified just over 70% of the time. This is comparable with the 80% accuracy achieved by Belousova et al. (2002) using classification trees, but falls short of the accuracy promised by pilot testing.

Based on the confusion matrix provided for this forest, the dataset was simplified by reducing or modifying attributes, collapsing together provenance classes and culling redundant specimens to produce the first forest (labeled ‘Alpha’ in Table 5.1). Some provenance classes were collapsed together to broaden the petrologic environment for those classes that have common genetic features, e.g. a hydrothermal class was created to reflect the importance of fluid infiltration around intrusions and along faults.

The number of attributes were reduced from 18 to 12. The following oxides were removed from consideration for this model run: B_2O_3 , Cr_2O_3 , ZnO , SrO , Fe_2O_3 (any Fe_2O_3 measurements were recalculated and added to FeO), and V_2O_3 . Elements such as Cr, Zn, and Sr are measured in a limited number of studies, but the specimens did not have appreciable amounts of these elements, so they were not considered reliable indicators of provenance.

Low populations in some provenance classes also prompted a revision of classes into broader rock types, using the classes of Henry and Guidotti (1985) as a guide. Even though random forests can accommodate variable class size, five classes out of the total 39 potential classes had no usable data in the dataset, and nine classes were underrepresented (<6 analyses). Pegmatites, in particular, had a high misclassification rate, as might be expected given the complex growth environment of pegmatites with an influence of fluid influx and the expected interactions with the country rocks. Nonetheless, pegmatites are also the best-represented class in the dataset, containing nearly half the specimens. During revision of the dataset, where there was more than

Table 5.1 – Table of forests grown, with out-of-bag error rate and attributes on which the forest was trained.

Run	Analyses	OOB (%)	Attributes
Pilot	275	3	12: B ₂ O ₃ , SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO, MnO, MgO, Li ₂ O, CaO, Na ₂ O, K ₂ O, F
Alpha	2553	9.98	18: B ₂ O ₃ , SiO ₂ , Al ₂ O ₃ , TiO ₂ , Cr ₂ O ₃ , Fe ₂ O ₃ , FeO, Mn, Mg, V ₂ O ₃ , ZnO, SrO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F, Cl
A	1354	8.39	12: SiO ₂ , Al ₂ O ₃ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F, Cl
B	1354	8.5	12: SiO ₂ , Al ₂ O ₃ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F, Cl
C	1354	6.38	12: SiO ₂ , Al ₂ O ₃ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F, Cl
D	1354	5.15	12: SiO ₂ , Al ₂ O ₃ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F
E	1354	4.03	11: SiO ₂ , Al ₂ O ₃ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, K ₂ O, F
F	1544	8.24	10: SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, F
G	1398	5.31	10: SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, F
H	1500	7.1	10: SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, F
I	1485	6.46	10: SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, F
J	1485	5.8	10: SiO ₂ , Al ₂ O ₃ , TiO ₂ , FeO (total), MnO, MgO, CaO, Li ₂ O, Na ₂ O, F

a single possible lithologic influence, the one that appeared to exhibit the greatest control was used as the labeled class. Four forests based on 12 chemical attributes were grown from 1355 specimens (B, C, D, and E; see Appendix B for literature sources). These 12 chemical attributes were SiO₂, Al₂O₃, FeO (total), MnO, MgO, CaO, Li₂O (measured and calculated), Na₂O, K₂O, F, and Cl.

In Table 5.2, the out-of-bag rate (and thus the real error rate) goes down as classes are broadened. Forests B, C, D, and E focused on determining the most accurate classification that could be achieved; i.e., finding a labeled set of data that could produce the lowest out-of-bag rate. Forests F, G, H, I, and J were developed with the provenance fields set out in Henry and Guidotti (1985) as a guide. The OOB rates are comparable, showing that this method correctly classifies tourmalines according to provenance about 95 percent of the time. Broader classes can more easily accommodate the wide variety of tourmaline compositions in differing rock types, but do not offer significant advantages over the method of Henry and Guidotti (1985).

Tourmaline compositions define the forest in the same way they define the fields in Henry and Guidotti (1985). Forest D's OOB rate improves upon Forest C's OOB rate just by having a set of specimens (in this case, metamafic-hosted pegmatite samples) re-labeled with a more 'accurate' provenance class. In order to "teach" the forest which tourmalines come from which rock types, ideal tourmaline compositions must be tagged. In terms of error rates, Forest E is the most 'successful' forest grown during this study,

Table 5.2 – Table of forests with the class definitions used.

Forest	B	C	D	E	F	G
Classes	9	8	8	7	10	8
	Granite	Granite	Granite	Granite and aplite	Granite	Granites + Aplites + Pegmatites Li-poor
	Aplite	Aplite	Aplite		Aplite	Granites + Aplites + Pegmatites Li-rich
	Pegmatite	Pegmatite and Li Pegmatite	Pegmatite and Li Pegmatite	Pegmatite and Li Pegmatite	Pegmatite	Li-rich granite + pegmatite + aplite with Calcareous host
	Li Pegmatite				Li Pegmatite	
	Metapelites and Metapsammites	Metapelites and Metapsammites	Metapelites and Metapsammites	Metapelites and Metapsammites	Metapelites Metapsammites	Metapelites and Metapsammites
	Calcareous	Calcareous	Calcareous	Calcareous	Calcareous	Calcareous
	Metamafic	Metamafic	Metamafic	Metamafic	Metamafic	Metamafic
	Metaevaporites	Metaevaporites	Metaevaporites	Metaevaporites	Metaevaporites	Metaevaporites
	Hydrothermal	Hydrothermal	Hydrothermal	Hydrothermal	Hydrothermal	Hydrothermal

Table 5.2 continued.

Forest	H	I	J
Classes	10	8	8
	Granites + Aplites + Pegmatites Li-poor	Granites + Aplites + Pegmatites Li-poor	Granites + Aplites + Pegmatites Li-poor
	Granites + Aplites + Pegmatites Li-rich	Granites + Aplites + Pegmatites Li-rich	Granites + Aplites + Pegmatites Li-rich
	Li-rich granite + peg + aplite with Calcareous host	Li-rich granite + peg + aplite with Calcareous host	Li-rich granite + peg + aplite with Calcareous host
	Metapelites and Metapsammites	Metapelites and Metapsammites	Metapelites and Metapsammites
	Calcareous	Calcareous	Calcareous
	Metamafic	Metamafic	Metamafic
	Pegmatites, granites and aplites with mafic host		
	Metaevaporites	Metaevaporites	Metaevaporites
	Hydrothermal alteration of metapelites	Hydrothermal	Hydrothermal
	Hydrothermal alteration of pegmatites/granites/felsic rocks		

In Table 5.3, the `class.error` value has been converted to a percentage, showing which provenance classes yielded the most false positive results. For example, in Forest E, 22% of the specimens labeled as hydrothermal tourmaline were incorrectly classified in other classes. Consistently represented among the classes with the highest rates of false positives were classes containing tourmalines from calcareous deposits and hydrothermal alteration of pre-existing sediments. Forest E demonstrated that random forests could classify tourmaline specimens according to provenance with less than 5% OOB error.

Subsequent forests were trained toward a set of provenance classes informed by Henry and Guidotti (1985). Re-labeling and removing some data improved the OOB rate (to 5.8% in the final Forest J), but the forests continued to have difficulties correctly classifying some tourmalines in metaevaporites, lithium-poor pegmatites, aplites, and granites, and calcareous rocks. Confusion between these classes likely results from a lithology containing tourmaline without a distinct chemical signal (as per the overlapping fields on the ternary diagram in Figure 1.2), or from a blend of provenance signals from multiple sources within a specimen.

Table 5.3 – Summary table of forests grown during this study. The number of specimens is the number of tourmaline analyses that were used to grow the forest. The OOB rate is a rough estimate of the real error rate. The most important element is determined using the mean Gini index. The top 3 misclassified classes are given in percent, derived from class.error output in the randomForest function.

Forest	Specimens	OOB rate (%)	Most important element	Top 3 misclassified classes (from class.error)
A	1354	8.47	Ca	Pegmatites(58%) Calcareous (31%) Aplites (25%)
B	1354	8.5	Ca	Pegmatites (55%) Calcareous (31%) Metamafic (25%)
C	1354	6.38	Ca	Metamafic (26%) Calcareous (26%) Aplites (22%)
D	1354	5.15	Ca	Calcareous (37%) Aplites (36%) Hydrothermal (24%)
E	1354	4.03	Li	Hydrothermal (22%) Calcareous (15%) Metamafic (10%)
F	1544	8.24	Mg	Pegmatites (57%) Calcareous (40%) Aplites (33%)
G	1398	5.31	Mg	Calcareous (25%) Hydrothermal (22%) Pegmatites, granites and aprites, Li-poor (9.8%)
H	1500	7.1	Mg	Mafic-hosted pegmatites (40%) Calcareous (23%) Metapelite-hosted hydrothermal (25%)
I	1486	6.46	Mg	Calcareous (26%) Metaevaporites (20%) Hydrothermal (16%)
J	1485	5.8	Mg	Metaevaporites (26%) Pegmatites, granites and aprites, Li-poor (18%) Calcareous (15%)

CHAPTER 6 – APPLICATION

Compared to the ternary AFM provenance diagram of Henry and Guidotti (1985), the random forest has a different set of advantages and challenges. Random forests are newly grown every time data is added, so there is no single ‘model’ in the traditional sense

In the case of tourmaline, random forests have difficulty drawing finite lines between increasingly more specific provenance classes: a broader classification scheme produced more accurate results than a granular one. Early forests had low accuracy when presented with data labeled for 39 classes, but greatly improved in accuracy when presented with data labeled for less than 10 classes. Compositional shifts in environmental fluids are recorded continuously in tourmaline, making it difficult to select a ‘golden spike’ to define a provenance class based on chemical composition alone. For example, the hydrothermal class (Class 8 in Forest J) is indicative of fluid movement without recrystallization, but cannot be further subdivided to reflect the diverse fluid environments in which tourmaline forms without losing accuracy (e.g., hydrothermal tourmalines attributed to a marine environment cannot be differentiated from hydrothermal tourmalines associated with heated fluids during metamorphism.) Additional information that can be obtained from a single crystal could resolve some ambiguity that occurs as a result of broad provenance classes; boron or lithium isotopes could provide some information about fluids, as suggested by Marschall and Jiang (2011). Random forests can incorporate this information, provided that it is available for all data in the training set.

It is erroneous to assume that classes which occur in the provenance probability tables are necessarily indications of chemical influence on the specimen, only a measure of chemical similarity to tourmalines in that provenance class. In the case of hydrothermal tourmalines (or tourmalines with a strong probability (>0.5) of being classified as hydrothermal), probability

results for classes other than the one in which the tourmaline is classified may be interpreted as influences from country rock. Prudence should be exercised when applying this reasoning to detrital overgrowths in the absence of other textural information.

As an independent test, Forest J was selected for its low class.error with regard to hydrothermal tourmalines and used to classify detrital specimens from a study by Viator (2003) that centered on the Black Hills, South Dakota, United States. Viator's study area (Figure 6.1) is primarily comprised of Archean granites, pegmatites and banded iron formations that were overlain unconformably by sediments in the Paleozoic, and then uplifted and eroded in the Tertiary Laramide orogeny with some associated shallow intrusive igneous activity. The field area consists of Precambrian-age metapelitic schists, and quartzites (staurolite to upper sillimanite grade) and the Harney Peak granite (HPG). Some associated granitic- to rare-element-enriched pegmatites occur around the periphery of the HPG, and have a mineral assemblage of quartz, albite, alkali feldspar, muscovite and either biotite or tourmaline as the ferromagnesian phase. The HPG field is zoned, containing mostly tourmaline granite along the periphery and biotite granite in the core.

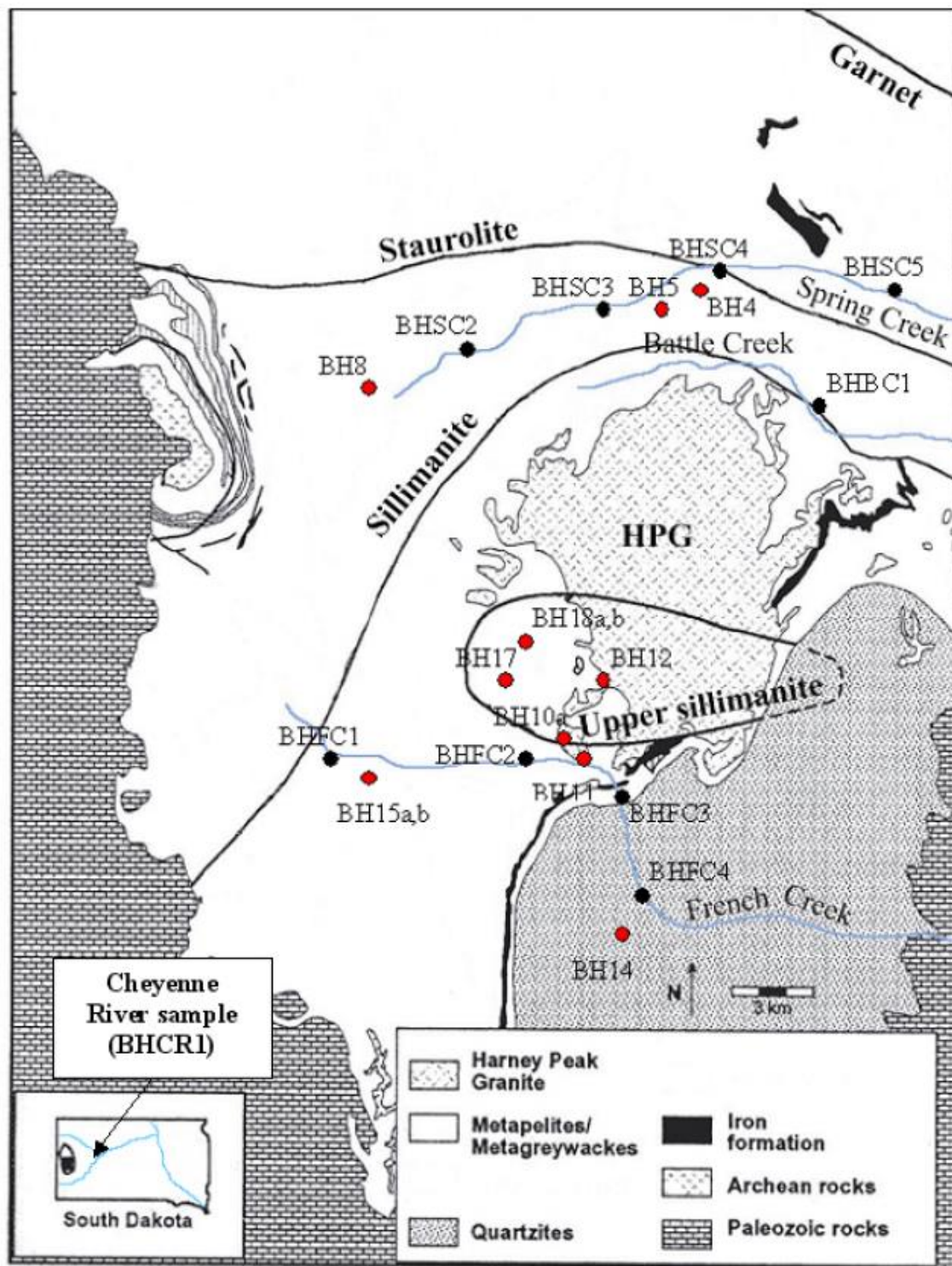


Figure 6.1 – Field area from Viator (2003) showing the field study area, including sample collection location. Red dots are potential tourmaline source samples and black dots are sediment samples from creeks and outwashes. Only data from BHSC3, BHFC4, and BHCR1 locations are used.

Viator found that there were roughly three types of tourmaline, corresponding with three lithologies in the Precambrian core: metamorphic, granitic, and rare-element enriched pegmatitic. Metamorphic tourmaline occurs as an accessory phase in mica schists that had been subjected to metamorphism between staurolite and upper sillimanite-grade. On ternary AFM provenance Al-Fe(tot)-Mg diagram, these metamorphic tourmalines plot in the fields corresponding to metapelites with an Al-saturating phase and metapelites without an Al-saturating phase. On the Ca-Fe(tot)-Mg diagram, they plot in Ca-poor metapelites. Granitic tourmaline (“normal” tourmaline) occurs as an accessory phase in the periphery of the HPG. On Al-Fe(tot)-Mg ternary diagrams, these tourmalines plot in Li-poor granitoids and associated pegmatites and aplites, and in metapelites, reflecting the mixing of provenance signals that occurs in a contact aureole. Rare-element enriched pegmatitic tourmalines were collected from the Etta Pegmatite, and are strongly zoned from core to rim. Core analyses plot in Li-poor granitoids, while rim analyses are Li-rich and plot in the Li-rich granitoids, pegmatites, and associated aplites field. These are potential sources for tourmaline analyses in Viator’s work, and the spread of data was used to define the bounds of possible provenance on ternary provenance diagrams. These areas of possible provenance indicated provenance sources for detrital tourmaline (see dotted lines in Figure 6.2, 6.3).

Tourmaline data from three sediment samples were selected from Viator (2003) with a total of 103 tourmaline analyses that can be classified: BHSC3a, BHFC4, and BHCR1. BHSC3a was collected in Spring Creek, north of the HPG and just south of the regional staurolite isograd; the geology of the area is dominated by metagraywackes and metapelites (Figure 6.1).

BHFC4 was collected in French Creek, south of the HPG field inside the regional sillimanite isograd; the geology of the area is dominated by quartzites. BHCR1 was collected near the Cheyenne River, 80km distant from the HPG field and represents a source that may include tourmaline inputs from other distal tourmaline-bearing lithologies as well as the HPG.

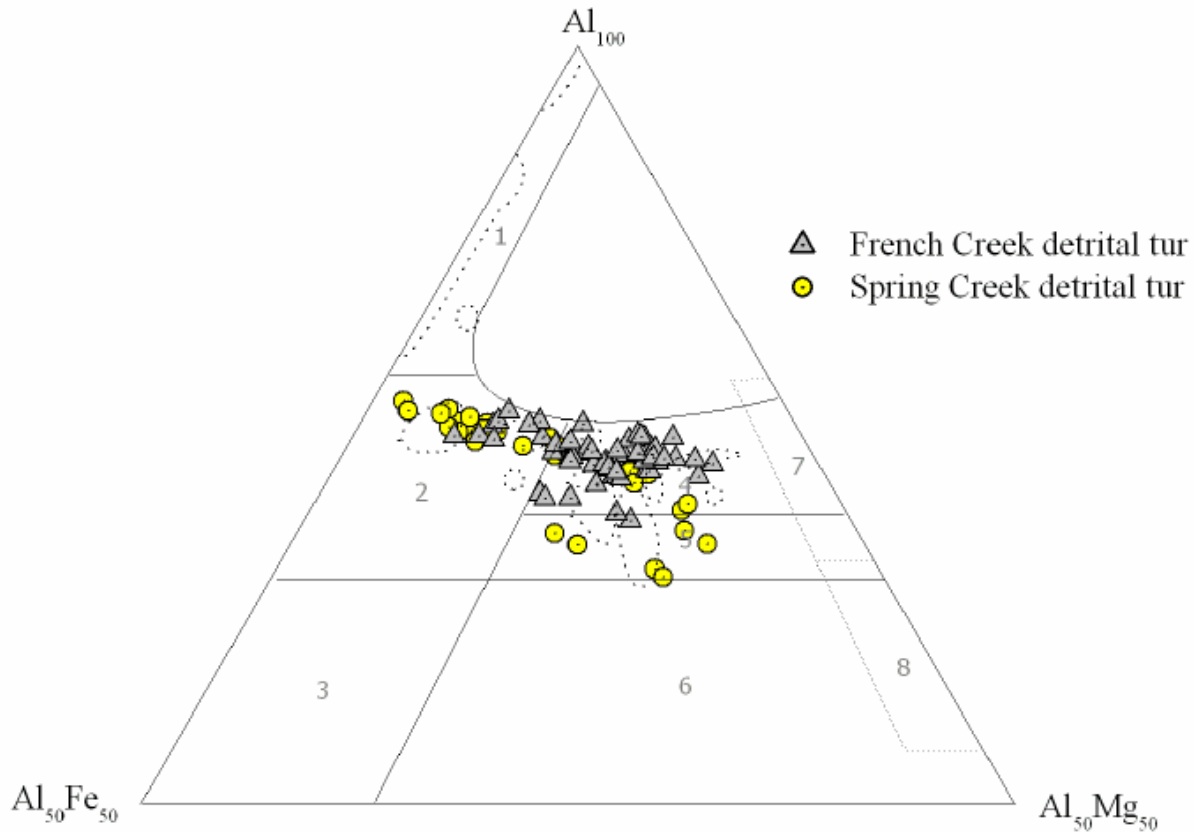


Figure 6.2 – Detrital tourmaline analyses from Viator (2003), plotted on Al-Fe (tot)-Mg ternary diagram after Henry and Guidotti (1985). Samples plotted are BHSC2, BHSC4, BHSC5, BHFC1, BHFC2, BHFC3, BHFC4. Dotted lines outline tourmaline compositions associated with potential source lithologies proximal to the study area. The numbered fields correspond to the following rock types: (1) Li-rich granitoid pegmatites and aplites, (2) Li-poor granitoids and associated pegmatites and aplites, (3) Fe^{3+} -rich quartz-tourmaline rocks (hydrothermally altered granites), (4) Metapelites coexisting with an Al-saturating phase, (5) Metapelites without an Al-saturating phase, (6) Fe^{3+} -rich quartz-tourmaline rocks, calc-silicate rocks, and metapelites, (7) Low-Ca metaultramafics and Cr, V-rich metasediments, and (8) Metacarbonates and meta-pyroxenites. (After Viator 2003)

Ternary diagrams provided by Viator (Figure 6.2, 6.3) include fields of possible tourmaline composition defined by tourmalines collected at outcrop from the field area.

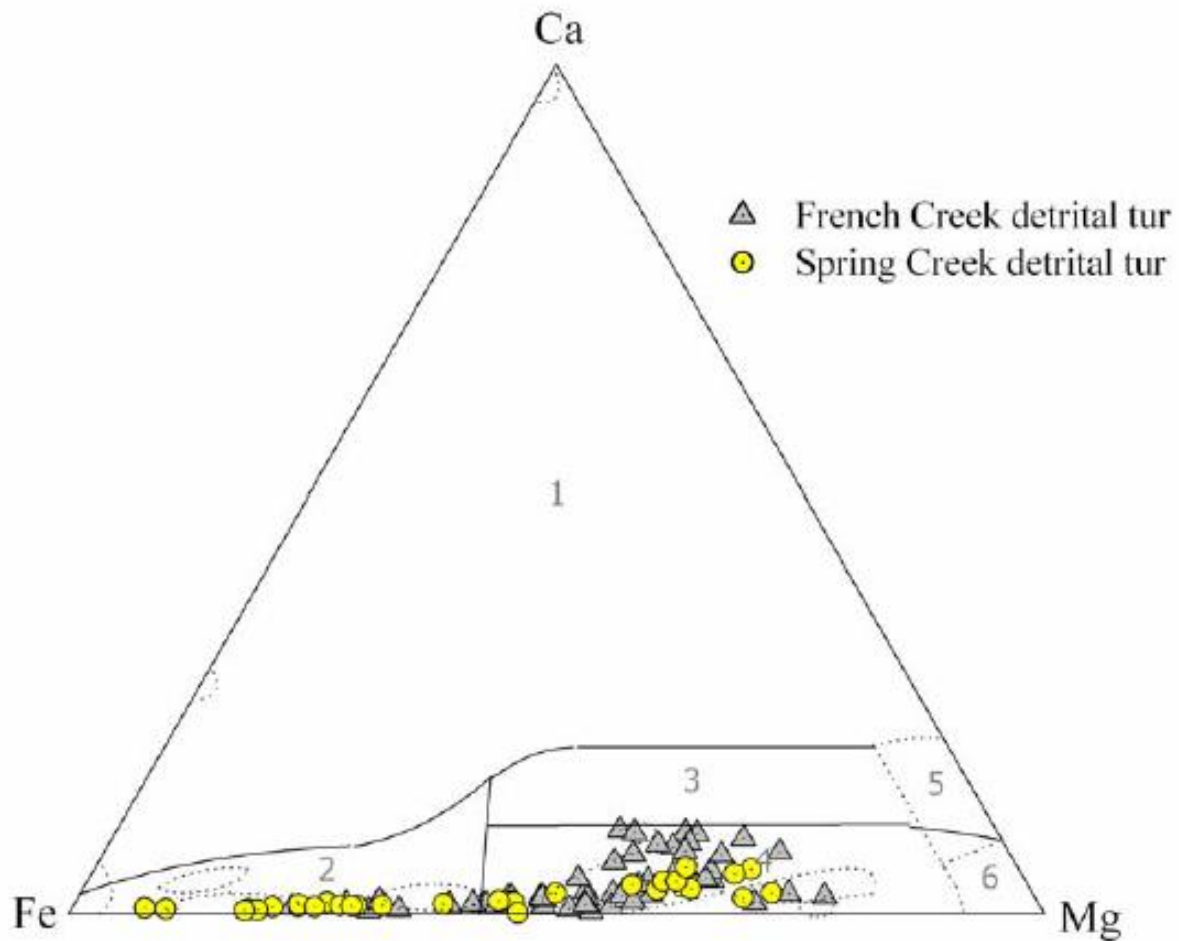


Figure 6.3 – Detrital tourmalines plotted on Henry and Guidotti's (1985) Ca-Fe(tot)-Mg ternary diagram. Samples plotted are BHSC2, BHSC4, BHSC5, BHFC1, BHFC2, BHFC3, BHFC4. Outlined areas define potential source rock compositions defined in Viator (2003). The numbered fields correspond to the following rock types: (1) Li-rich granitoid pegmatites and aplites, (2) Li-poor granitoids and associated pegmatites and aplites, (3) Ca-rich metapelites and calc-silicate rocks, (4) Ca-poor metapelites and quartz-tourmaline rocks, (5) Metacarbonates, and (6) Metaultramafics. (After Viator (2003)).

Based on the ternary provenance diagrams of Henry and Guidotti (1985), potential source lithologies for Spring Creek field area are Li-poor granitoids, pegmatites, and aplites, Al-saturated metapelites and metapsammites, Al-undersaturated metapelites and metapsammites (Figure 6.2) and Ca-poor metapelites (Figure 6.3). According to the random forest, the data from BHSC3a (Spring Creek) can be classified as mainly Li-poor granitoids, pegmatites, and aplites, metapelites and metapsammites, and hydrothermal tourmalines. Three of the analyses from BHSC3a were classified by the random forest as Li-rich granitoids, pegmatites, and aplites, which were not included in Viator's plot of Spring Creek data (Figures 6.2 and 6.3).

Tourmalines from BHFC4 (French Creek) are classified by the forest as hydrothermal, metapelites and metapsammites, with some Li-poor granitoids, pegmatites, and aplites. Viator's data classifies them as metapelites and metapsammites, and Li-poor granitoids, pegmatites, and aplites (Figures 6.2 and 6.3). There is good agreement between the random forest and Viator's ternary diagrams.

Tourmalines from BHCR1 (Cheyenne River) are classified by the forest as hydrothermal, metapelites and metapsammites, and metamafic. Most of the tourmalines from this locality plot in Li-poor granitoids, pegmatites, and aplites and Al-rich metapelites and metapsammites. Viator notes that these analyses had a bias toward metamorphic tourmaline, owing to the greater concentration of tourmaline in finer sand fractions (compared to the inclination of coarser sand fractions to develop from granitic and pegmatitic sources).

For all three localities, the random forest was able to produce classifications that match those given by Viator (Figure 6.4). Some discrepancies exist because the original ternary diagrams do not include a field that reflects the hydrothermal fluid origins of some tourmalines. Out of 103 Black Hills tourmaline analyses, only 4 are not classified as hydrothermal or in agreement with his ternary diagrams (Figures 6.2 and 6.3). Those four analyses were classified

as Li-rich granitoids, pegmatites, and aplites (3) and metamafic (1). They were not classified outside the expected provenance fields for the potential source units in the Black Hills (given in dotted outline in Viator's diagrams). These tourmalines may represent complex zoning during metamorphic events, or tourmaline transported from multiple metasedimentary units in the Black Hills.

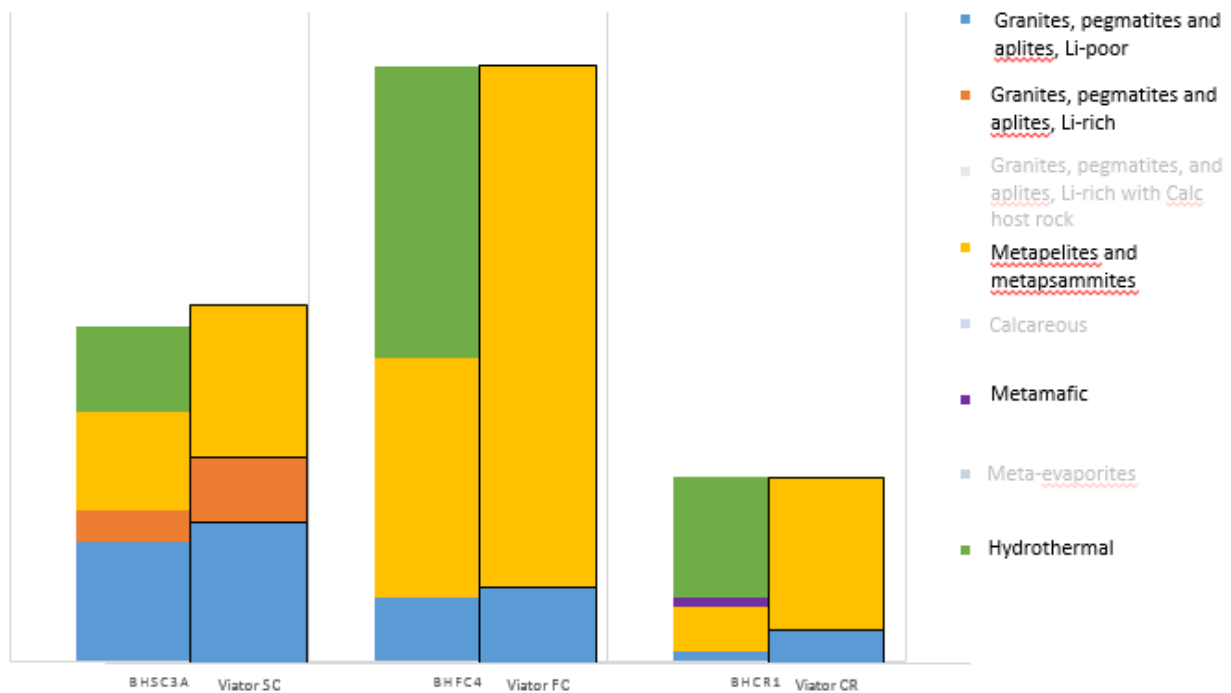


Figure 6.4 – Results from classification of 103 tourmaline specimens from the Black Hills, South Dakota, USA. For each of the three samples, the left vertical bar is the classification made by Forest J, and the right vertical bar is the original classification made by Viator (2003).

CHAPTER 7 - CONCLUSION

Tourmaline is a robust provenance indicator mineral. This study improves on the use of Henry and Guidotti (1985) ternary diagrams that are widely used to classify the likely provenance of tourmaline by using more of the chemical information available.

Using random forests, a relatively new statistical technique that has been used in geology to classify soil and ore samples, to classify tourmalines according to provenance is a novel approach. A database of tourmaline analyses was assembled from the literature and used to grow a series of random forests. Forest J, is capable of classifying tourmalines with about 95% accuracy and uses provenance classes that reflect petrogenetic conditions.

Further work should be directed at continuing to improve the ability of random forests to distinguish between chemically ambiguous classes and provide more accurate classifications, either through approaching zero-error results with the existing provenance class structure or creating more granular classifications. The randomForest technique can compensate for classes that are not well-populated and produces good results, but a subtype of random forests, weighted random forests, may potentially be able to account for provenance classes without a large population of specimens. Winham et al. (2013) showed the method also has some success in distinguishing between complex interactions in genetic data, paving the way toward provenance classes with finer distinctions.

The addition of other attributes or features to the random forest could also improve classification results. Mineral textures, mineral associations, and color might provide distinguishing features for populations of tourmaline specimens that have ambiguous provenance signals, i.e., these additional attributes can untangle the overlapping provenance fields from the Al-Fe-Mg ternary diagram in wide use from Henry and Guidotti (1985). Alternatively, the use of

a series of ‘nested’ random forests could provide more information about the provenance of a tourmaline, e.g., classifying tourmaline according to granite or pegmatite types. Initial classification with the forest described in this study can determine general provenance classification. Further classification could be done with a set of data labeled according to Cerny and Ercit’s classification of granitic pegmatite types (2005), continuing the work of Clarke et al. (1989).

REFERENCES CITED

- Abraham, K., Mielke, H., and Povondra, P. (1972) On the enrichment of tourmaline in metamorphic sediments of the Erzberg series, W.-Germany (NE-Bavaria). *Neue Jahrbuch für Mineralogie: Monatshefte*, 209-219.
- Ahn, J.H., and Buseck, P.R. (1998) Transmission electron microscopy of muscovite alteration of tourmaline. *American Mineralogist*, 83, 535-541.
- Attarchi, S., and Gloaguen, R. (2014) Classifying complex mountainous forests with L-Band SAR and LANDSAT data integration: a comparison among different machine learning methods in the Hyrcanian forest. *Remote Sensing*, 6, 3624-3647.
- Augustsson, C., Rüsing, T., Adams, C.J., Chmiel, H., Kocabayoğlu, M., Büld, M., Zimmermann, U., Berndt, J., and Kooijman, E., (2011) Detrital quartz and zircon combined: the production of mature sand with short transportation paths along the Cambrian West Gondwana margin, Northwestern Argentina. *Journal of Sedimentary Research*, 81, 284-298.
- Auricchio, C., Ottolini, L., and Pezzotta, F. (1999) Electron- and ion-microprobe analyses and genetic inferences of tourmalines of the foitite-schorl solid solution, Elba Island (Italy). *European Journal of Mineralogy*, 11, 217-225.
- Bačík, P., Uher, P., Cempírek, J., and Vaculovič, T. (2012) Magnesian tourmalines from plagioclase-muscovite-scapolite metaevaporite layers in dolomite marble near Prosetín, (Olešnice Unit, Moravicum, Czech Republic). *Journal of Geosciences*, 57, 143-153.
- Barton, R. Jr. (1969) Refinement of the crystal structure of buergerite and the absolute orientation of tourmalines. *Acta Crystallographica*, B25, 1524-1533.
- Baudron, P., Alonso-Sarría, F., García-Aróstegui, J. L., Cánovas-García, F., Martínez-Vicente, D., Moreno-Brotóns, J. (2013) Identifying the origin of groundwater samples in a multi-layer aquifer system with Random Forest classification. *Journal of Hydrology*, 499, 303-315.
- Belousova, E.A., Griffin, W.L., O'Reilly, S.Y., and Fisher, N.I. (2002a) Apatite as an indicator mineral for mineral exploration: trace-element compositions and their relationship to host rock type. *Journal of Geochemical Exploration*, 76, 45-69. .
- Belousova, E.A., Griffin, W.L., O'Reilly, S.Y., and Fisher, N.I. (2002b) Igneous zircon: trace element composition as an indicator of source rock type. *Contributions to Mineralogy and Petrology*, 143, 602-622.
- Bloomfield, M.J. (1997) Gem tourmaline pegmatite deposits. *Geology*, M.Sc., 149 p. University of Leicester, Leicester, UK.
- Bosi, F., Balić-Žunić, T. and Surour, A.A. (2010) Crystal structure analysis of four tourmaline from the Cleopatra's Mines (Egypt) and Jabal Zalm (Saudi Arabia) and the role of Al in the tourmaline group. *American Mineralogist*, 95, 510-518.

Bowman, H.L. (1902) On an Occurrence of Minerals at Haddam Neck, Connecticut, USA. *Mineralogical Magazine*, 13, 98-119.

Breaks, F.W., and Tindle, A.G. (2004) Rare-element granitic pegmatites of the Fort Hope field, north-central Ontario. In *Summary of Field Work and Other Activities 2004*, Ontario Geological Survey, Open File Report 6145, p. 11-1 to 11-9.

Breaks, F.W., Selway, J.B., and Tindle, A.G. (2003) Fertile peraluminous granites and related rare-element mineralization in pegmatites, Superior Province, northwest and northeast Ontario: Operation Treasure Hunt; Ontario Geological Survey, Open File Report 6099, 170 p.

Breaks, F.W., Tindle, A.G., and Selway, J.B. (2008) Electron microprobe and bulk rock and mineral compositions from rare-element pegmatites and peraluminous, S-type granitic rocks from the Fort Hope pegmatite field, north-central Superior Province of Ontario. Ontario Geological Survey, Miscellaneous Data Release 235.

Breiman, L., Friedman, J.H., Olshen, R.A., Stone, C.J., (1984) *Classification and Regression Trees*. Wadsworth, Belmont, CA.

Breiman, L (1996a) Bagging predictors. *Machine Learning*, 24, 123-140.

Breiman, L. (1996b) Out-of-bag estimation. Technical Report, Department of Statistics, University of California, Berkeley. <https://www.stat.berkeley.edu/~breiman/OOBestimation.pdf>. Accessed 7 March 2015.

Breiman, L. (1998) Randomizing outputs to increase prediction accuracy. Technical Report 518, University of California, Berkeley.

Breiman, L. (2001) Random forests. *Machine Learning*, 45, 5-32.

Bylander, T. and Hanzlik, D. (1999) Estimating generalization error using out-of-bag estimates. *Proceedings of the Sixteenth National Conference on Artificial Intelligence*, Orlando, Florida, 1126 p. <http://www.aaai.org/Papers/AAAI/1999/AAAI99-047.pdf> Accessed 7 March 2015.

Caruana, R. and Niculescu-Mizil, A. (2006) An empirical comparison of supervised learning algorithms. In Cohen, W., Moore, A., Eds., *Proceedings of the 23rd International Conference on Machine Learning*, New York, p. 161-168.

Cavaretta, G., and Puxeddu, M. (1990). Schorl-dravite-ferridravite tourmalines deposited by hydrothermal magmatic fluids during early evolution of the Larderello geothermal field, Italy. *Economic Geology*, 85(6), 1236-1251.

Cempírek, J., Novák, M., Ertl, A., Hughes, J.M., Rossman, G.R., and Dyar, M.D. (2006) Fe-bearing olenite with tetrahedrally coordinated Al from an abyssal pegmatite at Kutná Hora, Czech Republic: structure, crystal chemistry, optical and XANES spectra. *Canadian Mineralogist*, 44, 23-30.

Cerny, P. and Ercit, T.S. (2005) The classification of granitic pegmatites revisited. *Canadian Mineralogist*, 43, 2005-2026.

Challis, A., Grapes, R. and Palmer, K. (1995) Chromian muscovite, uvarovite and zirconian chromite: products of regional metasomatism in northwest Nelson, New Zealand. *Canadian Mineralogist*, 33, 1263-1284.

Chambers, J.M. and Hastie, T.J. (1992) Statistical models in S. Wadsworth & Brooks, Pacific Grove, CA.

Chaudhry, M.N., and Howie, R.A. (1976) Lithium tourmalines from the Meldon aplite, Devonshire, England. *Mineralogical Magazine*, 40, 747-751.

Clark, C.M. (2007) Tourmaline: structural formula calculations. *Canadian Mineralogist*, 45, 229-237.

Clarke, D.B., Reardon, N.C., Chatterjee, A.K., and Gregoire, D.C. (1989) Tourmaline composition as a guide to mineral exploration: a reconnaissance study from Nova Scotia using discriminant function analysis. *Economic Geology*, 84, 1921-1935.

Deer, W.A., Howie, R.A., and Zussman, J. (1962) Tourmaline. In: *Rock-forming Minerals*, 1, Wiley and Sons, New York.

Denil, M., Matheson, D., and de Freitas, N. (2014) Narrowing the gap: random forests in theory and in practice. *Proceedings of the 31st International Conference on Machine Learning*, 32, <http://www.jmlr.org/proceedings/>. Accessed 27 February 2015.

Dietrich, R.V. (1985) *The Tourmaline Group*. Van Nostrand Reinhold Company, New York, 300 p.

Dietterich, T. (2000) Ensemble methods in machine learning. *Lecture Notes in Computer Science*, 1857, 1-15.

Donnay, G. and Buerger, M.J. (1950) The determination of the crystal structure of tourmaline. *Acta Crystallographica*, 3, 379-388.

Donnay, G., Ingamells, C.O., and Mason, B.H. (1966) Buergerite, a new species of tourmaline. *American Mineralogist*, 50, 198-199.

Donnay, G. and Barton, R. Jr. (1972) Refinement of the crystal structure of elbaite and the mechanism of tourmaline solid solution. *Tschermaks Mineralogische und Petrographische Mitteilungen*, 18, 273-286.

Dutrow, B.L., and Henry, D.J. (2011) Tourmaline: a geologic DVD. *Elements*, 7, 301-306.

Dutrow, B.L., and Henry, D.J. (2016) Fibrous tourmaline: A sensitive probe of fluid compositions. *Canadian Mineralogist*, 54, 1-25.

Ertl, A., Tillmanns, E., Ntaflos, T., Francis, C., Giester, G., Körner, W., Hughes, J.M., Lengauer, C., and Prem, M. (2008) Tetrahedrally coordinated boron in Al-rich tourmaline and its relationship to the pressure-temperature conditions of formation. *European Journal of Mineralogy*, 20, 881-888.

Ertl, A., Giester, G., Schüssler, U., Brätz, H., Okrusch, M., Tillmanns, E., and Bank, H. (2013) Cu- and Mn-bearing tourmalines from Brazil and Mozambique: Crystal structures, chemistry and correlations. *Mineralogy and Petrology*, 107, 265-279.

Ethier, V.G., and Campbell, F.A.. (1977) Tourmaline concentrations in Proterozoic sediments of the southern Cordillera of Canada and their economic significance. *Canadian Journal of Earth Science*, 14, 2348-2363.

Griffin, W.L., Fisher, N.I., Friedman, J.H., and Ryan, C.G. (1997) Statistical techniques for the classification of chromites in diamond exploration samples. *Journal of Geochemical Exploration*, 59, 233-249.

Groat, L.A., Marshall, D.D., Giuliani, G., Murphy, D.C., Piercey, S.J., Jambor, J.L., Mortensen, J.K., Ercit, T.S., Gault, R.A., Mathey, D.P., Schwarz, D., Maluski, H., Wise, M.A., Wengzynowski, W., and Eaton, D.W. (2002) Mineralogical and geochemical study of the Regal Ridge Emerald Showing, Southeastern Yukon. *Canadian Mineralogist*, 40, 1313-1338.

Hastie, T., Tibshirani, R., and Friedman, J. (2009) *The Elements of Statistical Learning*. Springer-Verlag, New York, 763 p.

Haughton, P.D.W., Todd, S.P., and Morton, A.C. (1991) Sedimentary provenance studies. In Morton, A.C., Todd, S.P., and Haughton, P.D.W., Eds., *Developments in Sedimentary Provenance Studies*, Geological Society of London Special Publications, 57, 1-11.

Hawthorne, F.C. and Henry, D.J. (1999) Classification of the minerals of the tourmaline group. *European Journal of Mineralogy*, 11, 201-215.

Hawthorne, F.C., MacDonald, D.J., Burns, P.C. (1993) Reassignment of cation site occupancies in tourmaline: Al/Mg disorder in the crystal structure of dravite. *American Mineralogist*, 78, 265-270.

Hawthorne, F.C., and Dirlam, D.M. (2011) Tourmaline the indicator mineral: from atomic arrangement to Viking navigation. *Elements*, 7, 307-312.

Henry, D.J. (1981) Sulfide-silicate relations of the staurolite grade pelitic schists, Rangeley Quadrangle, Maine. Ph.D. dissertation, University of Wisconsin-Madison.

Henry, D.J. (2011) Spreadsheet for determining the tourmaline species based on an ordered distribution of elements in the tourmaline formula.
http://www.minsocam.org/msa/ammin/toc/2011/MJ11_Data/Henry_p895_11_TourmalineSpecies.xls. Accessed 7 March 2015.

Henry, D.J. and Dutrow, B.L. (1992) Tourmaline in a low grade clastic metasedimentary rock: an example of the petrogenetic potential of tourmaline. *Contributions to Mineralogy and Petrology*, 112, 203-218.

Henry, D.J. and Dutrow, B.L. (1996) Metamorphic tourmaline and its petrologic applications. In L.M. Anovitz and E.S. Grew, Eds., *Boron: Mineralogy, Petrology and Geochemistry*, 33, p. 503-557. *Reviews in Mineralogy*, Mineralogical Society of America, Chantilly, Virginia.

Henry, D.J. and Dutrow, B.L. (2011) The incorporation of fluorine in tourmaline: internal crystallographic controls or external environmental influences? *Canadian Mineralogist*, 49, 41-56.

Henry, D.J. and Dutrow, B.L. (2012) Tourmaline at diagenetic to low-grade metamorphic conditions: Its petrologic applicability. *Lithos* 154, 16-32.

Henry, D.J., and Guidotti, C.V. (1985) Tourmaline as a petrogenetic indicator mineral: an example from the staurolite-grade metapelites of NW Maine. *American Mineralogist*, 70, 1-15.

Henry, D.J., Lu, G., and McCabe, C. (1994) Epigenetic tourmaline in sedimentary red-beds: an example from the Silurian Rose Hill Formation, Virginia. *Canadian Mineralogist*, 32, 599-605.

Henry, D. J., Kirkland, B.L., and Kirkland, D.W. (1999). Sector-zoned tourmaline from the cap rock of a salt dome. *European Journal of Mineralogy* 11(2), 263-280.

Henry, D.J., Novak, M., Hawthorne, F.C., Ertl, A., Dutrow, B.L., Uher, P., Pezzotta, F. (2011) Nomenclature of the tourmaline-super group minerals. *American Mineralogist*, 96, 895-913.

Ho, T.K. (1998) The random subspace method for constructing decision forests. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 20, 832-844.

Hubert, J.F. (1962) A zircon-tourmaline-rutile maturity index and the interdependence of the composition of heavy mineral assemblages with the gross composition and texture of sandstones. *Journal of Sedimentary Petrology*, 32, 440-450.

Hughes, J.M., Ertl, A., Dyar, M.D., Grew, E.S, Shearer, C.K., Yates, M.G., and Guidotti, C.V. (2000) Tetrahedrally coordinated boron in a tourmaline: boron-rich olenite from Stoffhütte, Koralpe, Austria. *Canadian Mineralogist*, 38, 861-868.

Johnsson, M.J. (1993) The system controlling the composition of clastic sediments. In Johnsson, M.J., and Basu, A., Eds., *Processes Controlling the Composition of Clastic Sediments*, 284, 1-19. Geological Society of America Special Papers, Boulder, Colorado.

Kohavi, R., and Provost, F. (1998). Glossary of terms. *Machine Learning*, 30, 271-274.

Kowal-Linka, M. and Stawikowski, W. (2013) Garnet and tourmaline as provenance indicators of terrigenous material in epicontinental carbonates (Middle Triassic, S Poland). *Sedimentary Geology*, 291, 27-47.

Krynine, P.D. (1946) The tourmaline group in sediments. *Geology*, 54, 65-87.

Laurs, B.M., Dilles, J.H., and Snee, L.W. (1996) Emerald mineralization and metasomatism of amphibolite, Khaltaro granitic pegmatite – hydrothermal vein system, Haramosh Mountains, northern Pakistan. *Canadian Mineralogist*, 34, 1253-1286.

Liaw, A. and Wiener, M. (2002) Classification and Regression by randomForest. *R News*, 2-3, 18-22.

Marler, B., Borowski, M., Wodara, U., and Schreyer, W. (2002) Synthetic tourmaline (olenite) with excess boron replacing silicon in the tetrahedral site. *European Journal of Mineralogy*, 14, 763-771.

Marschall, H.R., and Jiang, S.Y. (2011) Tourmaline isotopes: no element left behind. *Elements*, 7, 313-319.

Marschall, H.R., Ludwig, T., Altherr, R., Kalt, A., and Tonarini, S. (2006) Syros metasomatic tourmaline: evidence for very high- $\delta^{11}\text{B}$ fluids in subduction zones. *Journal of Petrology*, 47, 1915–1942.

Marschall, H.R., Altherr, R., Kalt, A., and Ludwig, T. (2008) Detrital, metamorphic and metasomatic tourmaline in high-pressure metasediments from Syros (Greece): intra-grain boron isotope patterns determined by secondary-ion mass spectrometry. *Contributions to Mineralogy and Petrology*, 155, 703-717.

Mlynarczyk, M.S.J., and Williams-Jones, A.E. (2006) Zoned tourmaline associated with cassiterite: implications for fluid evolution and tin mineralization in the San Rafael Sn-Cu deposit, southeastern Peru. *Canadian Mineralogist*, 44, 347-365.

Modreski, P. J., Foord, E. E., and Barbosa, C. P. (1997) Crystal chemistry of uvite-dravite from the Brumado magnesite deposits, Bahia, Brazil. *Tourmaline 1997 International Symposium on Tourmaline*, Abstract Volume. 59-60.

Morgan, G.B. IV., and London, D. (1989) Experimental reactions of amphibolite with boron-bearing aqueous fluids at 200 MPa: implications for tourmaline stability and partial melting in mafic rocks. *Contributions to Mineralogy and Petrology*, 102, 281-297.

Morgan, G.B. VI, and London, D. (1999) Crystallization of the Little Three layered pegmatite-aplite dike, Ramona District, California. *Contributions to Mineralogy and Petrology*, 136, 310-330.

Morton, A. (1991) Geochemical studies of detrital heavy minerals and their application to provenance research. In Morton, A.C., Todd, S.P. and Haughton, P.D.W., Eds., *Developments in Sedimentary Provenance Studies*, Geological Society of London, 57, 31-45.

- Morton, A.C., and Hallsworth, C.R. (1994) Identifying provenance-specific features of detrital heavy mineral assemblages in sandstones. *Sedimentary Geology*, 90, 241-256.
- Morton, A.C. and Hallsworth, C.R. (1999) Processes controlling the composition of heavy mineral assemblages in sandstones. *Sedimentary Geology*, 124, 3-29.
- Neiva, A.M.R. (1974) Geochemistry of tourmaline (schorlite) from granites, aplites and pegmatites from northern Portugal. *Geochimica et Cosmochimica Acta*, 38, 1307-1317.
- Novák, M., and Cempírek, J. (2010) Granitic pegmatites and mineralogical museums in Czech Republic. IMA 2010 Field Trip Guide CZ2. *Acta Mineral Petrogr Field Guide Series* 6, Szeged, pp 1-56.
- Novák, M., Ertl, A., Povondra, P., Galiova, M.V., Rossman, G.R., Pristacz, H., Prem, M., Giester, G., Gadas, P., and Skoda, R., (2013) Darrellhenryite, $\text{Na}(\text{LiAl}_2)\text{Al}_6(\text{BO}_3)_3\text{Si}_6\text{O}_{18}(\text{OH})_3\text{O}$, a new mineral from the tourmaline supergroup. *American Mineralogist*, 98, 1886-1892.
- O'Brien, J., Spry, P.G., Nettleton, D., Xu, R., and Teale, G.S. (2015) Using random forests to distinguish gahnite compositions as an exploration guide to Broken Hill-type Pb-Zn-Ag deposits in the Broken Hill domain, Australia. *Journal for Geochemical Exploration*, 149, 74-86.
- Pahlavan Rad, M.R., Toomanian, N., Khormali, F., Brungard, C.W., Komaki, C. B., and Bogaert, P. (2014) Updating soil survey maps using random forest and conditioned Latin hypercube sampling in the loess derived soils of northern Iran. *Geoderma*, 232-234, 97-106.
- Povondra, P., and Vrana, S. (1996) Tourmaline and associated minerals in alkali-feldspar orthogneiss near Hluboké nad Vltavou, southern Bohemia. *Journal of the Czech Geological Society*, 41, 191-200.
- Pettijohn, F.J., Potter, P.E., and Siever, R. (1987) *Sand and sandstone*. Springer, New York, 553 p.
- R Core Team (2014). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.
- Robnik-Šikonja, M. (2004) Improving random forests. In Boulicaut, J., Esposito, F., Giannotti, F., and Pedreschi, D., Eds., *Machine Learning: ECML 2004 15th European Conference on Machine Learning*, Pisa, Italy, September 20-24, Springer, Berlin, 359-370.
- Schapire, R.E. (1990) The strength of weak learnability. *Machine Learning*, 5, 197-227.
- Schreyer, W. (2000) Is the partitioning of boron between tourmaline and muscovite dependent on the crystallization environment? *Journal of the Czech Geological Society*, 45, 13-20.
- Sengupta, N., Sengupta, P., and Sachan, H.K. (2011) Aluminous and alkali-deficient tourmaline from the Singhbhum Shear Zone, East Indian shield: Insight for polyphase boron infiltration during regional metamorphism. *American Mineralogist*, 96, 752-767.

Sevastjanova, I., Hall, R., and Alderton, D. (2012) A detrital heavy mineral viewpoint on sediment provenance and tropical weathering in SE Asia. *Sedimentary Geology*, 280, 179-194.

Sheng, L., Zhang, T., Niu, G., Wang, K., Tang, H., Duan, Y., and Li, H. (2015) Classification of iron ores by laser-induced breakdown spectroscopy (LIBS) combined with random forest (RF). *Journal of Analytical Atomic Spectrometry*, 30, 453-458.

Shruthi, R., Kerle, N., Jetten, V., and Stein, A. (2014) Object-based gully system prediction from medium resolution imagery using Random Forests. *Geomorphology*, 216, 283-294.

Soares, D.R., Beurlen, H., Barreto, S.d., Da Silva, M. R. R., and Ferreira, A.C.M. (2008) Compositional variation of tourmaline-group minerals in the Borborema Pegmatite Province, Northeastern Brazil. *Canadian Mineralogist*, 46, 1097-1116.

Sun, H.T. (2007) Tourmalinites in Neoproterozoic metaevaporitic deposit of Duruchaus Formation, Damara Belt, Central Namibia. PhD dissertation, Louisiana State University.

Suttner, L.J. (1974) Sedimentary petrographic provinces: an evaluation. In: *Paleogeographic Provinces and Provinciality: Special Publication – Society of Economic Paleontologists and Mineralogists*. 75-84.

Tibshirani, R. (1996) Bias, variance and prediction error for classification rules. <http://www.utstat.toronto.edu/~tibs>. Accessed 25 February 2015.

Tindle, A.G., Breaks, F.W., Selway, J.B. (2002) Tourmaline in petalite-subtype granitic pegmatites: evidence of fractionation and contamination from the Pakeagama and Separation Lake areas of northwestern Ontario, Canada. *Canadian Mineralogist*, 40, 753-788.

Trumbull R.B., Krienitz M.S., Grundmann G., and Wiedenbeck, M. (2009) Tourmaline geochemistry and $\delta^{11}\text{B}$ variations as a guide to fluid–rock interaction in the Habachtal emerald deposit, Tauern Window, Austria. *Contributions to Mineralogy and Petrology* 157: 411-427.

Van de Kamp, P.C. (2010) Arkose, subarkose, quartz sand, and associated muds derived from felsic plutonic rocks in glacial to tropical humid climates. *Journal of Sedimentary Research*, 80, 895-918.

Van den Bleeken, G., Corteel, C., and Van den haute, P. (2007) Epigenetic to low-grade tourmaline in the Gdoutmont metaconglomerates (Belgium): a sensitive prove of its chemical environment of formation. *Lithos*, 95, 165-176.

Van Hinsberg, V.J. (2011) Preliminary experimental data on trace-element partitioning between tourmaline and silicate melt. *Canadian Mineralogist*, 49, 153-163.

Van Hinsberg, V.J., Henry, D.J., and Marschall, H.R. (2011a) Tourmaline: an ideal indicator of its host environment. *Canadian Mineralogist*, 49, 1-16.

Van Hinsberg, V.J., Henry, D.J., and Dutrow, B.L. (2011b) Tourmaline as a petrologic forensic mineral: A unique recorder of its geologic past. *Elements*, 7, 327-332.

Van Hinsberg, V.J. and Marschall, H.R. (2007) Boron isotope and light element sector zoning in tourmaline: implications for the formation of B-isotopic signatures. *Chemical Geology*, 238, 141-148.

Van Hinsberg, V.J. and Schumacher, J.C. (2007) Intersector element partitioning in tourmaline: a potentially powerful single crystal thermometer. *Contributions to Mineralogy and Petrology*, 153, 289-301.

Verikas, A., Gelzinis, A., and Bacauskiene, M. (2011) Mining data with random forests: a survey and results of new tests. *Pattern Recognition*, 44, 330-349.

Vermeesch, P. and Garzanti, E. (2015) Making geological sense of 'Big Data' in sedimentary provenance analysis. *Chemical Geology*, 409, 20-27.

Viator, D. (2003) Detrital tourmaline as an indicator of provenance: a chemical and sedimentological study of modern sands from the Black Hills, South Dakota. Master's thesis.

Weltje, G.J. (2002) Quantitative analysis of detrital modes: statistically rigorous confidence regions in ternary diagrams and their use in sedimentary petrology. *Earth-Science Reviews*, 57, 211-253.

Weltje, G.J., and Von Eynatten, H. (2004) Quantitative provenance analysis of sediments: review and outlook. *Sedimentary Geology*, 171, 1-11.

Winham, S.J., Freimuth, R.R., and Biernacka, J.M. (2013) A weighted random forests approach to improve predictive performance. *Statistical Analysis and Data Mining*, 6, 496-505.

Whitney, D. and Evans, B.W. (2010) Abbreviations for names of rock-forming minerals. *American Mineralogist*, 95, 185-187.

Wunder, B., Berryman, E., Plessen, B., Rhede, D., Koch-Muller, M., and Heinrich, W. (2015) Synthetic and natural ammonium-bearing tourmaline. *American Mineralogist*, 100, 250-256

Yavuz, F., Karakaya, N., Yıldırım, D.K., Karakaya, M.Ç., and Kumral, M. (2014) A Windows program for calculation and classification of tourmaline-supergroup (IMA-2011). *Computers & Geosciences*, 63, 70-87.

Žáček, V., Petrov, A., and Hyršl, J. (1998) Chemistry and origin of povondraite-bearing rocks from Alto Chapare, Cochabamba, Bolivia. *Journal of the Czech Geological Society*, 59-67.

APPENDIX A – R CODE

This is sample code from the R software environment. Two examples of output are included.

```
options(error=recover)
library(randomForest)
par(mfrow=c(2,2))
Data.Forest=read.table("E:/2016d.txt", sep="\t",header=T)
X.matrix=as.matrix(Data.Forest)
X.matrix=X.matrix[,-c(1,11)]
Y.Class=c(
  rep(1, 138-2),
  rep(2, 718-138),
  rep(3, 875-718),
  rep(4, 1158-875),
  rep(5, 1195-1158),
  rep(6, 1283-1195),
  rep(7, 1323-1283),
  rep(8, 1486-1323)
)
scramble=sample(1:1485)      #Creates dataset 'scramble' by
randomly sampling the dataset from 1 to 1355
train.=scramble[1:990]      #Creates dataset 'train.' by
scrambling data tuples from 1-894
test.=scramble[990:1485]    #Creates dataset 'test.' by
scrambling data tuples from 894-1355
table(Y.Class)
dim(Y.Class)
dim(train.)
dim(X.matrix)
fit.rf <- randomForest(X.matrix[train.],
  ],factor(Y.Class[train.]),ntree=500,importance=T,proximity=T)
print(fit.rf)
imp <- importance(fit.rf)
round(imp[,ncol(imp)],d=3)
varImpPlot(fit.rf)

names.=c('SiO2', 'Al2O3', 'TiO2', 'FeO', 'MnO', 'MgO', 'CaO',
  'Li2O', 'Na2O', 'F')
imp2 <- imp[,ncol(imp)] #MeanDecreaseGini
imp2 <- 100*imp2/sum(imp2) #Sum to 100
par(mfrow=c(1,1))      #Sets graphics view to one row, one
column of images
barplot(sort(imp2),horiz=T,xlab="Variable Importance",
  xlim=c(0,max(imp2)+.5),
```



```

names=names.[order(imp2)],cex.axis=1.2,las=1)#,col=rainbow(p,sta
rt=3/6,end=4/6))
box()

#MDS plot (proximity plot)
library(RColorBrewer)
MDSplot(fit.rf, factor(Y.Class),pch=Y.Class)

x2 <- X.matrix[test.,]
y2 <- Y.Class[test.]

pred1 <- predict(fit.rf,newdata=x2,type="response")
table(pred1)
tab <- table(pred1,y2+18) #use +18 to help see which is column
and row
tab

1-sum(diag(tab))/sum(tab) #classification error rate

pred2 <- predict(fit.rf,newdata=x2,type="prob") #this gives the
probability for each class
pred2

#begin load of detrital test data
Data.Detrital=read.table("I:/detritalb.txt", sep="\t",header=T)
X2.matrix=as.matrix(Data.Detrital)
pred.detrital <-
predict(fit.rf,newdata=X2.matrix,type="response")
pred.detrital

table(pred.detrital)

#detrital test data probability
Data.Pdetrit=read.table("I:/detritalb.txt", sep="\t",header=T)
X3.matrix=as.matrix(Data.Pdetrit)
pred.pdetrit <- predict(fit.rf,newdata=X3.matrix,type="prob")
pred.pdetrit

table(pred.pdetrit)

#Load Viator Detrital test data
Data.Viator=read.table("E:/viator.txt", sep="\t",header=T)
X4.matrix=as.matrix(Data.Viator)
viaprob <- predict(fit.rf,newdata=X4.matrix,type="prob")
viaprob
viator <- predict(fit.rf,newdata=X4.matrix,type="response")
viator

```

```

> #detrital test data probability
> Data.Pdetrit=read.table("I:/detritalb.txt", sep="\t",header=T)
> X3.matrix=as.matrix(Data.Pdetrit)
> pred.pdetrit <- predict(fit.rf,newdata=X3.matrix,type="prob")
> pred.pdetrit
      1      2      3      4      5      6      7      8
1 0.326 0.142 0.252 0.064 0.004 0.012 0.010 0.190
2 0.214 0.058 0.040 0.086 0.000 0.020 0.004 0.578
3 0.700 0.140 0.004 0.004 0.000 0.124 0.000 0.028
4 0.380 0.174 0.026 0.014 0.000 0.098 0.000 0.308
5 0.734 0.102 0.002 0.026 0.000 0.028 0.000 0.108
6 0.652 0.254 0.000 0.000 0.000 0.034 0.000 0.060
7 0.738 0.130 0.010 0.024 0.000 0.034 0.002 0.062
8 0.690 0.186 0.072 0.002 0.000 0.014 0.000 0.036
9 0.000 0.010 0.000 0.500 0.102 0.190 0.148 0.050
10 0.068 0.010 0.004 0.220 0.004 0.020 0.012 0.662
11 0.004 0.008 0.000 0.246 0.082 0.440 0.162 0.058
12 0.008 0.006 0.000 0.422 0.078 0.238 0.182 0.066
13 0.002 0.000 0.000 0.710 0.006 0.034 0.040 0.208
14 0.018 0.002 0.070 0.424 0.010 0.008 0.000 0.468
15 0.146 0.020 0.006 0.320 0.000 0.046 0.000 0.462
16 0.308 0.098 0.048 0.048 0.000 0.118 0.002 0.378
17 0.020 0.010 0.124 0.416 0.018 0.000 0.000 0.412
18 0.004 0.000 0.020 0.542 0.002 0.098 0.004 0.330
19 0.374 0.036 0.068 0.160 0.000 0.234 0.016 0.112
20 0.008 0.002 0.000 0.854 0.004 0.024 0.002 0.106
21 0.000 0.004 0.002 0.642 0.002 0.050 0.022 0.278
22 0.246 0.184 0.072 0.066 0.000 0.042 0.008 0.382
23 0.064 0.014 0.036 0.082 0.000 0.034 0.002 0.768
24 0.004 0.004 0.010 0.346 0.010 0.518 0.048 0.060
25 0.028 0.012 0.004 0.630 0.002 0.036 0.076 0.212
26 0.000 0.004 0.004 0.088 0.302 0.026 0.010 0.566
27 0.458 0.014 0.112 0.032 0.004 0.164 0.154 0.062
28 0.128 0.080 0.078 0.030 0.034 0.268 0.252 0.130
attr(,"class")
[1] "matrix" "votes"

```

Figure A.1 – Example output from the probability response of randomForest’s predict function (Forest J). Specimens are rows, provenance classes are columns. In this set of data (Henry and Dutrow 1992), each specimen has been given a probability that it falls into a provenance class. Specimen 20, for example, has a 0.854 probability of being in Class 4 – Metapelites and metapsammites. Other specimens indicate significant confusion between classes; Specimen 14 has a 0.424 probability of being in Class 4 – Metapelites and metapsammites, but also a 0.468 probability of being in Class 8 – Hydrothermal.

```

>
> #begin load of detrital test data
> Data.Detrital=read.table("I:/detritalb.txt", sep="\t",header=T)
> X2.matrix=as.matrix(Data.Detrital)
> pred.detrital <- predict(fit.rf,newdata=X2.matrix,type="response")
> pred.detrital
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
  1  8  1  1  1  1  1  1  4  8  6  4  4  8  8  8  4  4  1  4  4  8  8  6  4  8  1  6
Levels: 1 2 3 4 5 6 7 8
>
> table(pred.detrital)
pred.detrital
1 2 3 4 5 6 7 8
9 0 0 8 0 3 0 8
> |

```

Figure A.2 – Example output from the classification response of randomForest’s predict function from the same forest (Forest J) built for Figure 4.2. Specimens are listed in the first row and predicted provenance classes in the second row; the ‘levels’ are provenance classes. In this example, we can see that Specimen 20 was given the predicted classification of Class 4 – Metapelites and metapsammites. Specimen 14, which had roughly equivalent probabilities for Class 4 and Class 8, was assigned a predicted provenance class of 8. Because of the table of probabilities given in Figure A.1, we know that Class 8 narrowly outcompeted Class 4 for Specimen 14.

APPENDIX B – DESCRIPTIONS OF DATA SOURCES

Mineral abbreviations are given as suggested in Whitney and Evans (2010).

Number	Source	Summary of provenance
1	Abraham et al. 1972	Calc-silicate rocks and limestones directly overlain by a thin layer tourmaline-bearing metasedimentary rocks and quartzites, mica schists and greywackes.
2	Ahn 1998	Sericitization of tourmalines in the Harney Peak Granite, in the Precambrian terrane of the Black Hills, South Dakota.
3	Aurischio et al 1999	Fibrous tourmaline from Elba Island pegmatites, Italy
4	Bačík 2012	Magnesian tourmalines from plg-ms-scp metaevaporite layers in dolomitic marble, Moravicum, Czech Republic.
5	Bloomfield 1997	Tourmalines from an LCT pegmatite and metacalcareous host rocks, Sahatany Valley Madagascar.
6	Bowman 1902	Elbaite from lithium-rich pegmatite, Gillette Quarry, Haddam Neck, Connecticut.
7	Breaks 2008	Fare-element pegmatites and peraluminous, S-type granitic rocks from the Fort Hope pegmatite field, north-central Superior Province of Ontario, Canada.
8	Cavarretta 1990	Hydrothermal field in Italy.
9	Cempirek et al 2006	Abyssal pegmatite at Kutna Hora, Czech Republic.
10	Chaudhry and Howie 1976	Elbaite-schorl series tourmalines, from the (soda-lithia) Meldon aplite, Devonshire, England. Qz-orthoclase-ab-kfs-lepidolite-tur.
11	Deer et al. 1962	Elbaite from pegmatite in Sweden.
12	Donnay and Barton 1972	Elbaite from San Diego County, California, USA.
13	Donnay et al. 1966	Type specimen for buergerite, Mexquitic, San Luis Potosí, Mexico.
14	Dyar et al. 1998	Tourmalines that represent compositional extremes from a variety of plutonic, metamorphic and pegmatitic occurrences
15	Ertl 2013	Cu and Mn-bearing tourmalines from Brazil (granitic pegmatites near Salgandinho, Brazil,

		Paraiba-type) and Mozambique (elbaïtes from placer deposits associated with the Alto Ligonha pegmatite, Yuluchi Mountains.)
16	Groat 2002	Emerald and tourmalinites associated with a mica schist contact with a granitic pluton, Finlayson Lake District, southeastern Yukon, Canada.
17	Henry PhD (1981)	Staurolite-grade metapelitic schists, Maine.
18	Laurs 1996	Hydrothermal veins and granitic pegmatites associated with amphibolite lenses in a garnet-mica schist, Nanga Parbat – Haramosh massif, northern Pakistan.
19	Marschall 2006	Metasomatic tourmalines from granites, omp-ab hornfels, gln-, phe-ep-grt- and chl-schist and eclogites on Syros, Greece.
20	Marschall 2008	Tourmalines from marbles and gln-phe schists, from Syros, Greece.
21	Mlynarczyk 2006	Hydrothermal tourmaline associated with Sn-Cu deposits (tur-cst-qz-chl), southeastern Peru.
22	Modreski 1997	Magnesite deposits in Brazil.
23	Morgan 1999	Layered pegmatite-aplite dike, Ramona District, California.
24	Neiva 1974	Schorlites associated with granites, aplites and pegmatites intruding metawackes and phyllites from northern Portugal.
25	Novak 2010	Pegmatitic tourmaline
26	Povondra 1996	Tourmalines associated with fluid movements in an alkali feldspar orthogneiss, southern Bohemia.
27	Sengupta 2011	Foïtite- from borosilicate veins hosted in kyanite-quartzite veins in the Singhbhum Shear Zone, East Indian Shield.
28	Soares 2008	Tourmalines from LCT-family, rare-element-enriched pegmatites from the Borborema Pegmatite Province, northeastern Brazil.
29	Sun 2007 (unpublished thesis)	Metaevaporites.
30	Tindle et al. 2002	Tourmalines from petalite-subtype (lithium-rich) pegmatites from Pakeagama Lake and Separation Lake, Ontario, Canada.
31	Tindle 2003	Fertile peraluminous granites and related rare-element mineralization in pegmatites, Superior Province, northwest and northeast Ontario.
32	Trumbull 2008	A large collection of mostly schorl-dravite series tourmalines from fluorine-saturated

		emerald-bearing orbicular granites and bt-ms, bt-chl, bt, chl, and grt-ms schists.
33	Trumbull 2009	Associated with fluids from an emerald deposit, Tauern Window, Austria.
34	Van den Bleeken 2007	Tourmaline overgrowths from mid-greenschist facies conditions in the Gdumont metaconglomerate, Belgium
35	Žáček 1998	Oxy-dravite-povondraite series tourmalines from a metaevaporite, Alto Chapare, Cochabamba, Bolivia.

APPENDIX C – FOREST J DATA TABLE

Each entry is an individual chemical analysis of a tourmaline. They are arranged alphabetically by author. The ‘class’ column is which of the 8 provenance classes it was assigned in Forest J.

Information on Lithium content is not often directly measured (e.g., in a wet chem analysis), so this was calculated according to the Pesquera method.. If a specimen had both measured lithium content and calculated lithium content, the greater value was used. Iron content is given in terms of FeO; if there was measured Fe₂O₃, this was put in terms of FeO using the following equation:

$$([\text{Measured Fe}_2\text{O}_3 \text{ content}]/1.11135) + \text{Measured FeO} = \text{Total Iron as FeO}$$

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Abraham et al (1972)	4	35.88	30.85	0.99	7.69	0.00	7.66	1.63	0.00	1.66	0.07
Abraham et al (1972)	4	36.67	29.69	1.13	7.62	0.00	7.58	1.55	0.00	1.70	0.02
Ahn 1998	2	35.69	43.01	0.26	0.41	2.57	0.00	0.31	1.09	1.46	0.00
Auriscchio 1999	8	36.13	36.72	0.03	11.76	0.56	0.02	0.02	0.14	0.68	0.27
Auriscchio 1999	8	36.07	36.93	0.04	11.38	0.78	0.00	0.02	0.09	0.77	0.02
Auriscchio 1999	8	36.04	36.47	0.02	10.78	1.69	0.00	0.00	0.16	0.85	0.20
Auriscchio 1999	8	35.97	36.37	0.06	11.98	0.55	0.12	0.00	0.09	1.16	0.05
Auriscchio 1999	8	35.94	36.75	0.02	11.21	0.89	0.02	0.00	0.11	0.85	0.00
Auriscchio 1999	8	36.05	36.47	0.00	11.96	0.57	0.00	0.00	0.15	0.74	0.15
Auriscchio 1999	8	36.30	37.39	0.05	11.08	0.61	0.00	0.00	0.12	0.70	0.04
Auriscchio 1999	8	36.10	36.85	0.03	10.88	0.74	0.02	0.02	0.24	0.76	0.18
Auriscchio 1999	8	36.31	37.11	0.11	10.27	0.90	0.53	0.08	0.12	0.99	0.00
Auriscchio 1999	8	35.99	36.50	0.14	10.71	1.03	0.46	0.07	0.09	1.08	0.07
Auriscchio 1999	8	35.75	35.02	0.18	11.69	1.11	0.74	0.06	0.09	1.26	0.00
Auriscchio 1999	8	36.33	36.06	0.15	10.29	0.92	0.80	0.13	0.36	1.04	0.13
Auriscchio 1999	8	36.25	35.66	0.14	10.04	1.01	0.94	0.09	0.37	1.05	0.08
Auriscchio 1999	8	36.33	36.34	0.13	10.03	0.95	0.80	0.00	0.33	1.01	0.16
Auriscchio 1999	8	35.52	34.24	0.15	12.82	0.88	0.79	0.05	0.04	1.35	0.00
Auriscchio 1999	8	35.35	34.45	0.00	13.71	0.46	0.15	0.00	0.07	1.87	0.00
Bacik (2012)	5	38.42	34.33	0.00	2.48	0.00	8.71	0.13	0.00	1.62	0.00
Bacik (2012)	5	38.24	33.81	0.00	2.36	0.00	8.83	0.17	0.00	1.61	0.00
Bacik (2012)	5	37.80	35.56	0.00	2.11	0.00	8.10	0.39	0.00	2.34	0.00
Bacik (2012)	5	37.32	33.99	0.03	2.00	0.00	9.03	0.98	0.00	2.18	0.00
Bacik (2012)	5	37.54	32.79	0.03	0.60	0.00	11.13	1.66	0.00	1.84	0.00
Bacik (2012)	5	37.67	32.90	0.04	0.52	0.00	11.14	1.62	0.00	1.72	0.00
Bloomfield (1997)	2	35.78	35.18	0.10	8.54	1.64	0.00	0.03	0.75	1.83	0.35
Bloomfield (1997)	2	35.76	35.26	0.08	8.42	1.65	0.00	0.00	0.76	1.80	0.37
Bloomfield (1997)	2	35.49	35.16	0.00	8.68	1.65	0.00	0.00	0.69	1.78	0.37

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	35.70	35.25	0.00	8.52	1.68	0.00	0.00	0.73	1.78	0.38
Bloomfield (1997)	2	35.80	35.19	0.09	8.52	1.75	0.00	0.00	0.74	1.79	0.50
Bloomfield (1997)	2	35.59	35.40	0.08	8.47	1.72	0.00	0.30	0.70	1.83	0.31
Bloomfield (1997)	2	35.77	35.17	0.00	8.53	1.69	0.00	0.00	0.74	1.79	0.32
Bloomfield (1997)	2	35.51	35.51	0.00	8.55	1.59	0.00	0.00	0.68	1.80	0.41
Bloomfield (1997)	2	35.79	35.32	0.00	8.52	1.60	0.00	0.00	0.74	1.80	0.19
Bloomfield (1997)	2	35.71	35.29	0.00	8.58	1.74	0.00	0.00	0.70	1.83	0.41
Bloomfield (1997)	2	35.85	35.10	0.00	8.46	1.62	0.00	0.00	0.79	1.79	0.43
Bloomfield (1997)	2	35.92	35.30	0.00	8.36	1.71	0.00	0.00	0.77	1.82	0.38
Bloomfield (1997)	2	35.79	35.40	0.00	8.72	1.69	0.00	0.00	0.68	1.85	0.44
Bloomfield (1997)	2	35.76	35.34	0.00	8.62	1.74	0.00	0.03	0.70	1.81	0.33
Bloomfield (1997)	2	35.65	35.37	0.00	8.67	1.64	0.00	0.00	0.69	1.76	0.37
Bloomfield (1997)	2	35.72	35.13	0.00	8.50	1.70	0.00	0.04	0.75	1.81	0.30
Bloomfield (1997)	2	35.72	35.13	0.00	8.50	1.70	0.00	0.04	0.75	1.81	0.30
Bloomfield (1997)	2	35.92	35.32	0.00	8.73	1.65	0.00	0.00	0.72	1.81	0.32
Bloomfield (1997)	2	35.64	35.30	0.00	8.54	1.63	0.00	0.00	0.72	1.82	0.37
Bloomfield (1997)	2	35.83	35.40	0.07	8.47	1.74	0.00	0.00	0.73	1.78	0.25
Bloomfield (1997)	2	35.66	35.50	0.00	8.70	1.73	0.00	0.00	0.65	1.79	0.38
Bloomfield (1997)	2	35.74	35.26	0.08	8.51	1.66	0.00	0.00	0.74	1.83	0.34
Bloomfield (1997)	2	36.07	35.23	0.00	8.30	1.74	0.00	0.00	0.81	1.86	0.44
Bloomfield (1997)	2	35.85	35.39	0.00	7.09	1.45	0.00	0.03	1.02	2.33	0.68
Bloomfield (1997)	2	35.81	35.54	0.06	7.04	1.40	0.00	0.05	1.02	2.39	0.54
Bloomfield (1997)	2	36.05	35.66	0.12	6.81	1.61	0.00	0.04	1.04	2.40	0.73
Bloomfield (1997)	2	36.12	35.97	0.00	6.01	1.67	0.00	0.07	1.14	2.49	1.01
Bloomfield (1997)	2	36.47	36.50	0.07	4.89	1.93	0.00	0.11	1.28	2.62	1.02
Bloomfield (1997)	2	36.93	38.68	0.00	1.47	2.66	0.00	0.30	1.56	2.27	1.00
Bloomfield (1997)	2	37.12	38.19	0.00	0.88	2.17	0.00	0.25	1.83	2.11	0.70
Bloomfield (1997)	2	37.04	39.51	0.00	0.64	2.88	0.00	0.36	1.59	2.08	0.77

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	37.40	39.46	0.08	0.45	2.78	0.00	0.42	1.69	2.04	0.86
Bloomfield (1997)	2	37.30	39.59	0.00	0.35	2.82	0.00	0.40	1.67	2.07	0.86
Bloomfield (1997)	2	37.52	39.99	0.00	0.18	2.19	0.00	0.32	1.78	2.03	0.91
Bloomfield (1997)	2	37.57	39.54	0.00	0.50	1.95	0.00	0.42	1.83	2.02	0.86
Bloomfield (1997)	2	37.60	38.98	0.00	0.72	2.17	0.00	0.38	1.82	2.13	0.98
Bloomfield (1997)	2	37.94	38.01	0.10	1.57	2.23	0.00	0.25	1.82	2.26	0.78
Bloomfield (1997)	2	36.22	35.98	0.00	4.95	2.57	0.00	0.03	1.20	2.08	0.49
Bloomfield (1997)	2	36.03	36.00	0.00	4.86	2.47	0.00	0.00	1.20	2.02	0.48
Bloomfield (1997)	2	36.14	35.92	0.06	4.95	2.43	0.00	0.00	1.22	1.99	0.47
Bloomfield (1997)	2	35.84	36.10	0.00	5.15	2.47	0.00	0.00	1.12	2.09	0.54
Bloomfield (1997)	2	35.85	36.00	0.08	5.01	2.49	0.00	0.00	1.15	2.02	0.52
Bloomfield (1997)	2	36.00	35.88	0.00	4.87	2.48	0.00	0.03	1.21	2.03	0.48
Bloomfield (1997)	2	36.06	36.15	0.09	4.87	2.41	0.00	0.03	1.20	2.04	0.58
Bloomfield (1997)	2	36.10	36.12	0.00	4.93	2.58	0.00	0.00	1.17	2.02	0.48
Bloomfield (1997)	2	36.00	36.06	0.00	4.92	2.53	0.00	0.00	1.17	2.03	0.48
Bloomfield (1997)	2	35.67	35.84	0.00	4.91	2.58	0.00	0.00	1.15	2.10	0.45
Bloomfield (1997)	2	36.07	36.10	0.00	4.88	2.52	0.00	0.04	1.18	2.01	0.64
Bloomfield (1997)	2	35.44	35.79	0.09	4.98	2.45	0.00	0.00	1.14	1.98	0.52
Bloomfield (1997)	2	36.01	36.11	0.00	4.82	2.54	0.00	0.00	1.18	2.03	0.54
Bloomfield (1997)	2	36.08	36.20	0.00	4.86	2.46	0.00	0.03	1.19	2.03	0.34
Bloomfield (1997)	2	36.21	36.35	0.00	4.44	2.24	0.00	0.00	1.29	2.07	0.34
Bloomfield (1997)	2	35.95	36.29	0.06	3.89	2.23	0.00	0.09	1.37	2.56	0.80
Bloomfield (1997)	2	36.10	36.48	0.09	3.62	2.34	0.00	0.11	1.39	2.55	0.88
Bloomfield (1997)	2	36.07	36.42	0.07	2.94	2.74	0.00	0.11	1.45	2.56	0.96
Bloomfield (1997)	2	36.91	38.11	0.11	0.94	3.02	0.00	0.22	1.66	2.31	0.95
Bloomfield (1997)	2	37.94	38.67	0.00	0.36	1.54	0.00	0.37	2.07	1.97	0.91
Bloomfield (1997)	2	37.64	39.26	0.00	0.23	1.50	0.00	0.40	1.99	1.94	0.85
Bloomfield (1997)	2	37.48	40.59	0.00	0.00	1.07	0.00	0.15	1.92	1.88	0.66

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	37.44	40.18	0.00	0.00	1.09	0.00	0.00	1.96	1.92	0.75
Bloomfield (1997)	2	37.46	40.52	0.00	0.00	0.90	0.00	0.08	1.95	1.81	0.58
Bloomfield (1997)	2	37.31	40.23	0.08	0.00	0.88	0.00	0.18	1.97	1.80	0.58
Bloomfield (1997)	2	37.88	40.39	0.00	0.00	0.83	0.00	0.08	2.03	1.80	0.63
Bloomfield (1997)	2	37.10	40.45	0.08	0.00	0.97	0.00	0.26	1.90	1.86	0.72
Bloomfield (1997)	2	37.68	40.17	0.00	0.00	1.12	0.00	0.20	1.99	1.81	0.64
Bloomfield (1997)	2	38.21	39.73	0.08	0.00	1.08	0.00	0.03	2.11	1.88	0.78
Bloomfield (1997)	2	37.84	39.56	0.00	0.00	1.18	0.00	0.00	2.07	1.90	0.71
Bloomfield (1997)	2	37.68	39.82	0.00	0.00	1.10	0.00	0.03	2.03	1.88	0.88
Bloomfield (1997)	2	37.09	40.22	0.00	0.00	1.16	0.00	0.32	1.90	1.83	0.89
Bloomfield (1997)	2	37.88	39.47	0.00	0.00	1.32	0.00	0.36	2.06	1.94	0.81
Bloomfield (1997)	2	37.42	40.54	0.08	0.04	1.17	0.00	0.15	1.89	1.86	0.70
Bloomfield (1997)	2	37.83	40.01	0.00	0.00	1.09	0.00	0.00	2.03	1.92	0.62
Bloomfield (1997)	2	37.81	41.78	0.00	0.00	0.50	0.00	0.04	1.91	1.74	0.48
Bloomfield (1997)	2	37.38	40.22	0.00	0.00	1.32	0.00	0.21	1.91	1.88	0.55
Bloomfield (1997)	2	37.38	40.45	0.06	0.00	0.91	0.00	0.18	1.95	1.86	0.68
Bloomfield (1997)	2	37.25	40.38	0.08	0.00	1.02	0.00	0.12	1.92	1.86	0.74
Bloomfield (1997)	2	37.47	40.65	0.08	0.00	0.92	0.00	0.08	1.93	1.88	0.81
Bloomfield (1997)	2	37.73	39.95	0.08	0.00	1.14	0.00	0.04	2.02	1.92	0.71
Bloomfield (1997)	2	37.47	40.32	0.00	0.00	1.01	0.00	0.00	1.96	1.89	0.82
Bloomfield (1997)	2	38.10	39.55	0.00	0.00	1.04	0.00	0.00	2.13	1.88	0.82
Bloomfield (1997)	2	38.05	39.65	0.08	0.00	1.09	0.00	0.00	2.10	1.89	0.67
Bloomfield (1997)	2	35.10	33.84	0.11	12.65	0.45	0.93	0.04	0.29	1.87	0.23
Bloomfield (1997)	2	35.40	34.05	0.00	12.58	0.43	0.77	0.00	0.32	1.84	0.28
Bloomfield (1997)	2	35.47	33.95	0.12	12.89	0.51	0.93	0.00	0.27	1.82	0.30
Bloomfield (1997)	2	35.35	33.55	0.18	13.06	0.50	0.56	0.03	0.27	1.84	0.30
Bloomfield (1997)	2	35.36	33.15	0.20	13.29	0.52	0.50	0.00	0.28	1.82	0.22
Bloomfield (1997)	2	35.63	33.25	0.11	13.70	0.56	0.55	0.00	0.22	1.84	0.35

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	35.33	33.17	0.17	13.60	0.57	0.48	0.03	0.21	1.94	0.23
Bloomfield (1997)	2	35.36	32.85	0.14	13.91	0.52	0.54	0.03	0.21	1.95	0.48
Bloomfield (1997)	2	35.86	35.62	0.11	7.78	1.26	0.18	0.15	0.90	2.39	0.80
Bloomfield (1997)	2	36.81	34.32	0.14	7.78	0.94	0.26	0.09	1.23	2.59	0.87
Bloomfield (1997)	2	34.75	34.48	0.17	11.68	0.65	0.35	0.10	0.31	1.87	0.47
Bloomfield (1997)	2	35.61	33.37	0.07	13.22	0.60	0.57	0.00	0.28	1.91	0.40
Bloomfield (1997)	2	35.72	34.11	0.18	12.55	0.53	0.44	0.04	0.34	1.74	0.41
Bloomfield (1997)	2	35.21	33.70	0.15	12.44	0.62	0.51	0.00	0.33	1.96	0.50
Bloomfield (1997)	2	35.05	33.81	0.21	13.04	0.50	0.55	0.04	0.21	1.85	0.31
Bloomfield (1997)	2	35.18	33.92	0.19	12.63	0.54	0.52	0.00	0.28	1.88	0.44
Bloomfield (1997)	2	34.86	33.78	0.23	13.10	0.56	0.56	0.03	0.17	1.92	0.25
Bloomfield (1997)	2	34.89	33.41	0.19	12.33	0.64	0.50	0.04	0.34	1.97	0.52
Bloomfield (1997)	2	35.10	33.48	0.13	11.84	0.70	0.48	0.04	0.44	2.10	0.62
Bloomfield (1997)	2	35.61	33.92	0.00	12.58	0.48	0.46	0.00	0.35	1.76	0.27
Bloomfield (1997)	2	35.61	33.84	0.18	12.79	0.52	0.47	0.03	0.32	1.77	0.33
Bloomfield (1997)	2	35.57	33.96	0.13	12.53	0.58	0.46	0.04	0.33	1.81	0.27
Bloomfield (1997)	2	35.47	34.23	0.09	12.66	0.48	0.44	0.00	0.28	1.57	0.20
Bloomfield (1997)	2	36.60	35.20	0.16	7.79	1.07	0.21	0.09	1.08	2.55	1.04
Bloomfield (1997)	2	35.95	35.22	0.11	7.63	1.14	0.15	0.15	1.01	2.42	1.05
Bloomfield (1997)	2	35.54	34.17	0.13	12.97	0.61	0.48	0.00	0.22	1.83	0.29
Bloomfield (1997)	2	35.33	34.56	0.07	12.74	0.49	0.39	0.00	0.21	1.53	0.15
Bloomfield (1997)	2	35.21	33.81	0.14	12.73	0.50	0.47	0.06	0.28	1.82	0.31
Bloomfield (1997)	2	35.36	33.88	0.11	12.46	0.61	0.52	0.00	0.32	1.87	0.38
Bloomfield (1997)	2	35.02	34.61	0.14	11.28	0.71	0.37	0.06	0.39	1.99	0.51
Bloomfield (1997)	2	35.76	35.98	0.07	6.76	1.66	0.13	0.14	0.96	2.48	0.88
Bloomfield (1997)	2	36.03	35.75	0.16	6.63	1.64	0.12	0.16	1.05	2.42	0.72
Bloomfield (1997)	2	36.48	35.72	0.00	6.56	1.64	0.13	0.16	1.12	2.40	0.80
Bloomfield (1997)	2	35.87	35.42	0.12	7.67	1.33	0.16	0.13	0.94	2.29	0.87

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	36.06	35.15	0.15	7.60	1.31	0.17	0.12	1.01	2.36	0.98
Bloomfield (1997)	2	36.07	35.64	0.00	7.26	1.49	0.15	0.13	0.98	2.44	0.94
Bloomfield (1997)	2	36.35	35.62	0.10	7.37	1.54	0.14	0.10	0.99	2.39	0.92
Bloomfield (1997)	2	35.97	35.94	0.06	7.46	1.62	0.16	0.09	0.88	2.33	0.91
Bloomfield (1997)	2	35.85	35.46	0.13	7.58	1.40	0.12	0.10	0.93	2.35	0.81
Bloomfield (1997)	2	35.89	35.19	0.16	8.69	1.27	0.10	0.06	0.80	2.20	0.72
Bloomfield (1997)	2	35.39	33.96	0.09	12.41	0.56	0.23	0.00	0.34	1.56	0.25
Bloomfield (1997)	2	35.41	33.83	0.11	12.34	0.63	0.24	0.00	0.35	1.64	0.29
Bloomfield (1997)	2	35.40	34.02	0.06	12.67	0.56	0.26	0.00	0.28	1.40	0.17
Bloomfield (1997)	2	35.55	34.18	0.06	12.90	0.54	0.26	0.00	0.24	1.39	0.11
Bloomfield (1997)	2	35.55	34.40	0.06	12.87	0.63	0.27	0.04	0.21	1.53	0.11
Bloomfield (1997)	2	35.52	34.35	0.08	12.78	0.60	0.22	0.00	0.23	1.41	0.14
Bloomfield (1997)	2	35.41	34.33	0.00	12.78	0.58	0.24	0.00	0.22	1.42	0.09
Bloomfield (1997)	2	35.66	34.38	0.06	12.79	0.58	0.28	0.00	0.25	1.45	0.09
Bloomfield (1997)	2	35.61	34.35	0.06	13.03	0.58	0.28	0.00	0.20	1.45	0.17
Bloomfield (1997)	2	35.47	34.21	0.08	12.54	0.56	0.22	0.00	0.29	1.42	0.12
Bloomfield (1997)	2	35.61	34.36	0.08	13.12	0.61	0.26	0.00	0.18	1.50	0.09
Bloomfield (1997)	2	35.51	34.17	0.00	12.67	0.58	0.27	0.00	0.28	1.46	0.20
Bloomfield (1997)	2	35.47	34.28	0.00	12.99	0.53	0.30	0.00	0.21	1.49	0.14
Bloomfield (1997)	2	35.56	34.06	0.12	12.99	0.58	0.28	0.00	0.24	1.61	0.26
Bloomfield (1997)	2	35.03	33.65	0.18	13.56	0.63	0.34	0.00	0.11	1.84	0.27
Bloomfield (1997)	2	35.08	33.76	0.15	13.29	0.65	0.30	0.00	0.15	1.88	0.29
Bloomfield (1997)	2	34.53	33.71	0.16	13.28	0.63	0.35	0.00	0.09	1.89	0.35
Bloomfield (1997)	2	34.91	33.66	0.19	13.18	0.61	0.28	0.00	0.17	1.80	0.27
Bloomfield (1997)	2	35.02	33.66	0.11	13.05	0.64	0.26	0.00	0.20	1.89	0.24
Bloomfield (1997)	2	35.03	33.55	0.16	13.33	0.52	0.31	0.03	0.18	1.90	0.30
Bloomfield (1997)	2	34.91	33.52	0.22	13.27	0.67	0.30	0.00	0.16	1.87	0.32
Bloomfield (1997)	2	35.15	33.49	0.21	13.06	0.64	0.26	0.00	0.23	1.78	0.31

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	35.00	33.73	0.18	13.45	0.68	0.31	0.00	0.11	1.85	0.19
Bloomfield (1997)	2	35.04	33.43	0.24	13.28	0.64	0.33	0.03	0.19	1.86	0.31
Bloomfield (1997)	2	34.90	33.64	0.12	12.52	0.73	0.31	0.03	0.27	1.92	0.39
Bloomfield (1997)	2	37.52	40.38	0.00	0.00	0.19	0.00	0.09	2.09	1.71	0.76
Bloomfield (1997)	2	37.48	40.98	0.00	0.00	0.14	0.00	0.18	2.02	1.80	0.67
Bloomfield (1997)	2	37.12	41.19	0.08	0.00	0.38	0.00	0.17	1.91	1.72	0.60
Bloomfield (1997)	2	37.30	40.72	0.08	0.00	0.33	0.00	0.19	2.00	1.80	0.83
Bloomfield (1997)	2	37.65	41.00	0.00	0.00	0.12	0.02	0.09	2.04	1.74	0.62
Bloomfield (1997)	2	38.24	40.04	0.08	0.00	0.30	0.00	0.15	2.20	1.78	0.65
Bloomfield (1997)	2	37.76	40.29	0.00	0.00	0.31	0.00	0.12	2.11	1.80	0.63
Bloomfield (1997)	2	37.34	40.79	0.00	0.00	0.40	0.00	0.13	1.99	1.75	0.69
Bloomfield (1997)	2	37.20	40.28	0.00	0.00	0.38	0.00	0.17	2.03	1.76	0.72
Bloomfield (1997)	2	37.58	40.25	0.00	0.00	0.48	0.00	0.13	2.07	1.80	0.60
Bloomfield (1997)	2	37.53	40.70	0.00	0.00	0.30	0.00	0.09	2.04	1.72	0.54
Bloomfield (1997)	2	37.84	40.23	0.00	0.00	0.42	0.00	0.12	2.11	1.83	0.66
Bloomfield (1997)	2	37.87	41.98	0.00	0.00	0.18	0.00	0.00	1.94	1.58	0.34
Bloomfield (1997)	2	37.66	42.16	0.00	0.00	0.19	0.00	0.00	1.89	1.72	0.32
Bloomfield (1997)	2	37.57	41.91	0.00	0.00	0.14	0.00	0.00	1.92	1.61	0.46
Bloomfield (1997)	2	37.55	42.06	0.00	0.00	0.20	0.00	0.00	1.89	1.58	0.18
Bloomfield (1997)	2	38.06	40.37	0.08	0.04	0.45	0.00	0.09	2.11	1.77	0.68
Bloomfield (1997)	2	37.38	40.25	0.00	0.00	0.41	0.00	0.14	2.05	1.81	0.74
Bloomfield (1997)	2	37.96	42.64	0.00	0.00	0.16	0.00	0.03	1.88	1.61	0.20
Bloomfield (1997)	2	37.10	39.83	0.00	0.00	0.25	0.00	0.20	2.10	1.69	0.48
Bloomfield (1997)	2	37.39	40.15	0.00	0.00	0.26	0.00	0.21	2.09	1.69	0.68
Bloomfield (1997)	2	37.66	40.41	0.00	0.04	0.29	0.00	0.21	2.08	1.76	0.70
Bloomfield (1997)	2	37.58	40.27	0.08	0.00	0.36	0.00	0.23	2.08	1.75	0.65
Bloomfield (1997)	2	37.93	40.48	0.00	0.05	0.35	0.00	0.24	2.10	1.78	0.72
Bloomfield (1997)	2	37.98	40.37	0.00	0.00	0.33	0.00	0.21	2.13	1.79	0.88

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	37.80	40.35	0.00	0.00	0.42	0.00	0.22	2.09	1.79	0.79
Bloomfield (1997)	2	37.80	40.44	0.00	0.07	0.42	0.00	0.25	2.07	1.79	0.83
Bloomfield (1997)	2	37.83	40.46	0.00	0.06	0.45	0.00	0.26	2.07	1.75	0.98
Bloomfield (1997)	2	38.05	40.41	0.08	0.06	0.35	0.00	0.23	2.12	1.79	0.81
Bloomfield (1997)	2	37.77	40.42	0.07	0.00	0.36	0.00	0.23	2.09	1.81	0.78
Bloomfield (1997)	2	37.70	40.48	0.00	0.00	0.29	0.00	0.25	2.09	1.76	0.65
Bloomfield (1997)	2	38.00	40.71	0.00	0.00	0.23	0.00	0.23	2.10	1.83	0.79
Bloomfield (1997)	2	38.06	40.76	0.06	0.00	0.20	0.00	0.25	2.11	1.77	0.86
Bloomfield (1997)	2	37.75	40.50	0.00	0.00	0.21	0.00	0.23	2.10	1.77	0.72
Bloomfield (1997)	2	38.14	40.71	0.08	0.00	0.19	0.00	0.22	2.13	1.76	0.75
Bloomfield (1997)	2	37.99	40.64	0.00	0.00	0.16	0.00	0.23	2.12	1.79	0.78
Bloomfield (1997)	2	37.74	40.87	0.00	0.07	0.19	0.00	0.23	2.05	1.75	0.80
Bloomfield (1997)	2	37.96	40.57	0.00	0.05	0.17	0.00	0.23	2.12	1.77	0.68
Bloomfield (1997)	2	38.18	40.65	0.08	0.00	0.20	0.00	0.23	2.14	1.77	0.73
Bloomfield (1997)	2	37.72	38.42	0.00	0.82	2.13	0.06	0.24	1.89	2.09	0.85
Bloomfield (1997)	2	37.76	39.46	0.00	0.96	2.53	0.00	0.37	1.68	2.19	0.92
Bloomfield (1997)	2	37.93	40.90	0.00	0.11	1.74	0.00	0.42	1.81	1.94	0.90
Bloomfield (1997)	2	37.45	40.66	0.07	0.17	2.01	0.00	0.46	1.72	1.97	0.95
Bloomfield (1997)	2	37.57	40.47	0.00	0.25	2.44	0.00	0.32	1.68	2.01	0.83
Bloomfield (1997)	2	37.49	40.44	0.00	0.19	2.32	0.00	0.38	1.70	2.04	0.93
Bloomfield (1997)	2	36.98	40.73	0.08	0.18	2.26	0.00	0.36	1.62	1.98	0.93
Bloomfield (1997)	2	37.79	40.03	0.00	0.44	1.96	0.00	0.47	1.80	2.00	0.99
Bloomfield (1997)	2	37.28	39.78	0.08	0.53	1.98	0.00	0.42	1.75	1.99	0.67
Bloomfield (1997)	2	37.42	39.52	0.00	0.79	2.30	0.00	0.37	1.70	2.04	1.03
Bloomfield (1997)	2	37.84	38.53	0.00	1.17	2.19	0.02	0.26	1.82	2.19	0.82
Bloomfield (1997)	2	37.69	39.33	0.00	0.51	1.42	0.00	0.09	1.95	1.94	0.65
Bloomfield (1997)	2	38.35	40.15	0.00	0.54	1.34	0.00	0.10	1.94	1.90	0.57
Bloomfield (1997)	2	37.54	39.76	0.00	0.93	1.72	0.00	0.21	1.76	2.09	1.05

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	37.83	40.27	0.00	0.73	1.67	0.00	0.23	1.77	2.07	0.73
Bloomfield (1997)	2	37.62	40.36	0.00	0.74	1.72	0.00	0.16	1.73	2.06	1.16
Bloomfield (1997)	2	37.91	40.61	0.11	0.51	1.67	0.00	0.20	1.78	2.01	0.89
Bloomfield (1997)	2	38.08	41.14	0.00	0.05	1.52	0.00	0.25	1.84	1.93	1.06
Bloomfield (1997)	2	37.59	41.24	0.00	0.00	1.52	0.00	0.25	1.78	1.88	0.92
Bloomfield (1997)	2	38.19	41.46	0.08	0.00	1.21	0.00	0.21	1.88	1.84	0.80
Bloomfield (1997)	2	38.69	41.87	0.00	0.04	1.23	0.00	0.23	1.88	1.92	0.82
Bloomfield (1997)	2	39.01	41.96	0.07	0.09	1.47	0.00	0.24	1.86	1.01	0.90
Bloomfield (1997)	2	38.67	41.25	0.00	0.48	1.71	0.00	0.17	1.80	2.11	0.76
Bloomfield (1997)	2	38.86	41.23	0.00	0.71	1.65	0.00	0.16	1.79	2.17	1.14
Bloomfield (1997)	2	38.80	41.24	0.00	0.71	1.62	0.00	0.20	1.79	2.17	1.11
Bloomfield (1997)	2	39.12	41.06	0.00	1.07	1.95	0.00	0.29	1.73	2.37	1.24
Bloomfield (1997)	2	37.46	40.22	0.00	0.36	2.76	0.00	0.30	1.62	2.09	0.94
Bloomfield (1997)	2	37.05	40.25	0.08	0.29	2.70	0.00	0.29	1.59	2.06	0.91
Bloomfield (1997)	2	37.98	40.77	0.00	0.34	2.84	0.00	0.31	1.61	2.10	0.83
Bloomfield (1997)	2	37.24	40.41	0.08	0.34	2.71	0.00	0.32	1.58	2.03	1.06
Bloomfield (1997)	2	37.23	40.67	0.00	0.35	2.76	0.00	0.33	1.54	2.07	0.89
Bloomfield (1997)	2	37.41	40.53	0.00	0.29	2.67	0.00	0.28	1.61	2.05	0.85
Bloomfield (1997)	2	37.47	40.65	0.00	0.30	2.77	0.00	0.32	1.58	2.07	0.90
Bloomfield (1997)	2	37.59	40.41	0.00	0.28	2.65	0.00	0.29	1.65	2.08	1.00
Bloomfield (1997)	2	37.62	40.58	0.08	0.28	2.67	0.00	0.32	1.63	2.07	0.98
Bloomfield (1997)	2	37.26	40.31	0.13	0.25	2.59	0.00	0.38	1.63	1.98	1.00
Bloomfield (1997)	2	37.62	40.58	0.08	0.31	2.31	0.00	0.33	1.68	2.03	1.09
Bloomfield (1997)	2	38.18	41.31	0.08	0.29	2.65	0.00	0.34	1.61	2.20	0.85
Bloomfield (1997)	2	37.31	40.52	0.00	0.30	2.38	0.00	0.34	1.64	1.99	0.75
Bloomfield (1997)	2	38.83	42.20	0.00	0.17	1.44	0.00	0.14	1.80	1.92	0.71
Bloomfield (1997)	2	37.94	41.52	0.00	0.12	1.63	0.00	0.11	1.75	1.97	0.51
Bloomfield (1997)	2	38.29	41.70	0.08	0.10	1.53	0.00	0.12	1.79	1.94	0.65

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	2	38.05	41.73	0.00	0.11	1.36	0.00	0.12	1.78	1.92	0.56
Bloomfield (1997)	2	38.07	41.54	0.08	0.06	1.20	0.00	0.15	1.85	1.89	0.84
Bloomfield (1997)	2	38.14	40.59	0.00	0.34	1.76	0.00	0.21	1.83	2.04	0.83
Bloomfield (1997)	2	38.41	40.39	0.09	0.66	2.02	0.00	0.17	1.79	2.08	0.86
Bloomfield (1997)	2	38.11	39.99	0.00	0.73	2.10	0.00	0.13	1.77	2.13	0.98
Bloomfield (1997)	2	38.37	39.68	0.08	0.91	2.23	0.00	0.13	1.79	2.25	1.07
Bloomfield (1997)	2	38.40	40.00	0.08	1.07	2.02	0.00	0.07	1.76	2.18	0.75
Bloomfield (1997)	2	38.28	39.87	0.08	1.45	1.94	0.00	0.06	1.71	2.27	0.76
Bloomfield (1997)	2	38.98	40.55	0.00	1.43	1.77	0.00	0.06	1.74	2.18	0.67
Bloomfield (1997)	3	37.29	39.21	0.00	5.33	0.36	0.95	1.19	1.23	1.54	0.11
Bloomfield (1997)	3	36.14	34.37	1.03	10.98	2.46	0.54	0.71	0.33	2.05	0.07
Bloomfield (1997)	3	36.71	41.57	0.00	0.28	4.12	0.00	1.42	1.16	1.73	0.29
Bloomfield (1997)	3	36.98	40.24	0.00	0.13	5.28	0.00	1.26	1.19	1.90	0.36
Bloomfield (1997)	3	36.79	39.80	0.07	1.01	5.40	0.00	1.20	1.05	1.94	0.26
Bloomfield (1997)	3	36.80	39.40	0.06	2.74	4.43	0.02	1.12	0.95	1.92	0.23
Bloomfield (1997)	3	36.71	39.74	0.15	1.29	5.33	0.00	1.22	1.01	1.89	0.17
Bloomfield (1997)	3	36.63	39.25	0.15	2.74	4.53	0.03	1.16	0.93	1.94	0.29
Bloomfield (1997)	3	36.31	38.64	0.35	4.72	4.02	0.06	1.01	0.69	1.97	0.13
Bloomfield (1997)	3	36.47	37.44	0.58	6.89	3.51	0.13	0.85	0.55	1.96	0.18
Bloomfield (1997)	3	36.20	36.44	0.56	8.43	3.05	0.21	0.84	0.44	1.92	0.13
Bloomfield (1997)	3	36.19	35.03	0.82	10.44	2.65	0.50	0.78	0.32	2.06	0.22
Bloomfield (1997)	3	36.29	34.43	0.87	10.73	2.50	0.57	0.69	0.37	2.08	0.11
Bloomfield (1997)	3	36.11	34.19	0.90	11.21	2.51	0.55	0.72	0.29	2.06	0.08
Bloomfield (1997)	3	36.18	34.04	0.96	11.27	2.41	0.62	0.76	0.33	2.05	0.14
Bloomfield (1997)	3	36.14	33.99	0.93	11.31	2.36	0.69	0.79	0.33	2.02	0.07
Bloomfield (1997)	3	36.20	33.88	1.00	11.15	2.44	0.71	0.80	0.37	2.09	0.00
Bloomfield (1997)	3	36.32	33.99	1.02	11.15	2.38	0.73	0.81	0.38	2.08	0.17
Bloomfield (1997)	3	36.00	33.84	0.77	11.28	2.28	0.69	0.79	0.35	2.06	0.00

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	3	36.30	34.09	0.84	11.36	2.35	0.64	0.82	0.33	2.06	0.15
Bloomfield (1997)	3	36.20	34.40	0.90	11.04	2.43	0.57	0.83	0.32	2.03	0.15
Bloomfield (1997)	3	36.20	34.67	0.92	10.54	2.44	0.50	0.74	0.38	2.05	0.17
Bloomfield (1997)	3	36.16	36.44	0.78	8.51	3.19	0.22	0.86	0.40	1.98	0.20
Bloomfield (1997)	3	36.33	37.65	0.37	5.31	3.82	0.09	0.89	0.74	1.98	0.12
Bloomfield (1997)	3	36.68	38.60	0.29	2.79	4.84	0.02	1.11	0.95	1.94	0.21
Bloomfield (1997)	3	35.78	38.13	0.18	1.35	5.24	0.00	1.07	1.09	1.94	0.36
Bloomfield (1997)	3	37.12	39.28	0.05	1.52	5.28	0.02	1.06	1.08	1.95	0.26
Bloomfield (1997)	3	37.64	39.78	0.00	1.26	5.37	0.00	0.98	1.12	2.03	0.38
Bloomfield (1997)	3	37.06	39.82	0.07	0.38	5.70	0.00	1.03	1.14	1.97	0.23
Bloomfield (1997)	3	37.32	40.51	0.07	0.28	4.67	0.00	1.13	1.28	1.90	0.33
Bloomfield (1997)	3	37.42	41.45	0.06	0.20	3.49	0.00	1.20	1.38	1.85	0.39
Bloomfield (1997)	3	37.49	42.44	0.10	0.18	1.06	0.00	1.47	1.67	1.66	0.23
Bloomfield (1997)	3	36.61	41.05	0.23	2.10	1.07	0.93	1.92	1.38	1.36	0.12
Bloomfield (1997)	3	37.96	41.89	0.08	1.32	0.78	0.17	1.21	1.63	1.58	0.00
Bloomfield (1997)	3	36.85	41.02	0.25	2.67	1.19	0.20	2.06	1.29	1.34	0.00
Bloomfield (1997)	3	36.42	40.99	0.26	2.22	0.87	1.17	2.11	1.38	1.39	0.26
Bloomfield (1997)	3	37.75	42.42	0.00	0.13	0.51	0.00	1.42	1.80	1.66	0.32
Bloomfield (1997)	3	37.80	42.61	0.07	0.38	0.14	0.06	1.45	1.80	1.64	0.29
Bloomfield (1997)	3	36.83	40.11	0.24	3.10	0.90	0.68	1.88	1.37	1.40	0.15
Bloomfield (1997)	3	37.85	37.32	0.06	6.51	0.28	0.92	1.23	1.33	1.67	0.17
Bloomfield (1997)	3	36.03	40.17	0.29	2.51	0.60	0.54	1.88	1.42	1.40	0.19
Bloomfield (1997)	3	36.80	42.96	0.10	0.88	0.29	0.17	1.72	1.52	1.41	0.16
Bloomfield (1997)	3	36.77	42.50	0.00	0.02	0.56	0.00	1.96	1.68	1.50	0.41
Bloomfield (1997)	3	36.77	41.33	0.07	0.47	2.73	0.06	1.60	1.39	1.72	0.47
Bloomfield (1997)	3	36.98	40.31	0.06	0.40	3.69	0.12	1.31	1.40	1.80	0.30
Bloomfield (1997)	3	37.77	42.51	0.07	0.07	0.03	0.00	1.82	1.88	1.36	0.11
Bloomfield (1997)	3	36.93	40.67	0.27	1.98	0.24	0.28	2.87	1.62	1.19	0.57

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	3	37.56	41.25	0.00	0.34	0.28	0.00	3.43	1.92	1.04	0.98
Bloomfield (1997)	3	37.36	41.24	0.13	1.25	0.36	0.14	2.91	1.72	1.29	0.75
Bloomfield (1997)	3	37.47	41.08	0.08	0.29	0.20	0.02	3.30	1.95	1.08	0.84
Bloomfield (1997)	3	38.19	41.06	0.00	0.13	0.06	0.00	3.24	2.09	1.05	0.76
Bloomfield (1997)	3	37.92	41.55	0.00	0.14	0.14	0.00	3.14	1.98	1.17	0.84
Bloomfield (1997)	3	38.10	41.07	0.00	0.07	0.16	0.00	3.36	2.07	1.07	0.84
Bloomfield (1997)	3	38.13	41.07	0.00	0.00	0.18	0.00	3.37	2.09	1.12	1.04
Bloomfield (1997)	3	37.90	41.65	0.00	0.00	0.20	0.00	3.18	1.98	1.13	0.86
Bloomfield (1997)	3	38.04	41.17	0.06	0.05	0.30	0.00	2.86	2.03	1.25	0.71
Bloomfield (1997)	3	37.84	41.33	0.00	0.09	0.31	0.00	3.31	1.98	1.05	0.99
Bloomfield (1997)	3	37.80	41.19	0.00	0.12	0.26	0.00	3.29	2.00	1.07	1.04
Bloomfield (1997)	3	37.71	41.39	0.00	0.13	0.31	0.00	3.24	1.95	1.13	1.05
Bloomfield (1997)	3	35.48	29.67	1.09	16.33	0.52	2.06	1.30	0.00	2.08	0.12
Bloomfield (1997)	3	35.41	29.86	1.89	16.01	0.54	2.10	1.29	0.00	1.97	0.09
Bloomfield (1997)	3	35.85	29.34	1.72	14.11	0.64	3.68	1.51	0.00	2.04	0.07
Bloomfield (1997)	3	35.52	29.42	2.01	14.08	0.58	3.63	1.50	0.00	2.04	0.00
Bloomfield (1997)	3	35.76	29.63	1.98	14.86	0.64	3.22	1.50	0.00	1.99	0.00
Bloomfield (1997)	3	35.75	29.60	1.88	14.41	0.71	3.32	1.48	0.00	2.03	0.08
Bloomfield (1997)	3	35.74	29.74	1.87	14.37	0.72	3.34	1.38	0.00	2.08	0.07
Bloomfield (1997)	3	35.77	29.71	1.69	14.10	0.74	3.34	1.47	0.00	2.04	0.07
Bloomfield (1997)	3	36.22	30.05	1.85	14.34	0.65	2.95	1.24	0.00	2.03	0.09
Bloomfield (1997)	3	36.65	32.31	1.76	12.71	0.51	2.91	0.48	0.00	2.11	0.00
Bloomfield (1997)	3	36.81	33.61	1.32	11.79	0.37	1.31	0.34	0.70	2.15	0.00
Bloomfield (1997)	3	36.78	39.58	0.23	5.15	1.91	0.26	1.13	0.90	1.84	0.20
Bloomfield (1997)	3	37.10	42.69	0.00	1.51	0.56	0.03	1.34	1.43	1.62	0.22
Bloomfield (1997)	3	36.06	42.84	0.06	0.76	0.88	0.00	1.68	1.37	1.38	0.20
Bloomfield (1997)	3	36.60	43.76	0.15	0.90	0.47	0.03	1.42	1.36	1.50	0.11
Bloomfield (1997)	3	36.43	46.43	0.00	0.13	0.00	0.00	1.59	1.23	1.42	0.00

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	3	34.66	46.33	0.06	0.12	0.00	0.00	1.52	1.03	1.49	0.20
Bloomfield (1997)	3	36.60	44.24	0.07	0.16	0.27	0.00	1.49	1.47	1.48	0.00
Bloomfield (1997)	3	35.37	45.56	0.06	0.11	0.00	0.00	1.31	1.21	1.52	0.07
Bloomfield (1997)	3	39.90	46.09	0.00	0.25	0.05	0.00	1.64	1.67	1.40	0.00
Bloomfield (1997)	3	34.98	46.28	0.00	0.10	0.05	0.00	1.50	1.07	1.48	0.10
Bloomfield (1997)	3	36.72	44.49	0.00	0.15	0.00	0.00	1.47	1.50	1.44	0.20
Bloomfield (1997)	3	36.77	44.47	0.00	0.12	0.00	0.00	1.51	1.51	1.46	0.13
Bloomfield (1997)	3	36.22	43.62	0.12	0.70	0.31	0.07	1.45	1.39	1.45	0.14
Bloomfield (1997)	3	35.78	42.38	0.12	0.90	0.55	0.09	1.46	1.42	1.46	0.11
Bloomfield (1997)	3	35.95	45.60	0.00	0.09	0.06	0.00	1.38	1.27	1.43	0.12
Bloomfield (1997)	3	34.82	46.00	0.08	0.13	0.00	0.00	1.48	1.08	1.47	0.07
Bloomfield (1997)	3	35.23	46.22	0.00	0.15	0.05	0.00	1.54	1.10	1.49	0.10
Bloomfield (1997)	3	35.74	44.07	0.00	0.59	0.33	0.00	2.35	1.30	1.17	0.32
Bloomfield (1997)	3	35.00	45.15	0.00	0.19	0.11	0.00	2.30	1.18	1.18	0.15
Bloomfield (1997)	3	36.39	41.27	0.25	2.11	0.52	0.45	1.79	1.41	1.48	0.28
Bloomfield (1997)	3	35.37	29.51	1.26	15.03	0.92	2.60	1.31	0.00	2.18	0.13
Bloomfield (1997)	3	35.83	29.35	1.61	12.53	0.46	4.73	1.44	0.00	2.06	0.16
Bloomfield (1997)	3	35.74	28.76	1.95	12.84	0.55	4.76	1.56	0.00	2.03	0.12
Bloomfield (1997)	3	36.00	29.44	1.72	12.41	0.49	4.84	1.43	0.00	2.08	0.11
Bloomfield (1997)	3	37.13	31.27	1.00	11.13	1.13	3.66	0.97	0.00	2.17	0.11
Bloomfield (1997)	3	35.75	29.31	1.73	12.50	0.39	4.68	1.52	0.00	2.02	0.09
Bloomfield (1997)	3	36.07	28.95	1.59	12.33	0.47	5.16	1.61	0.00	2.05	0.10
Bloomfield (1997)	3	36.17	30.26	0.47	11.87	0.55	4.91	1.62	0.00	1.99	0.13
Bloomfield (1997)	3	35.89	26.56	1.18	12.36	0.79	7.43	1.61	0.00	1.73	0.08
Bloomfield (1997)	3	35.98	29.41	1.17	12.86	0.52	4.78	1.58	0.00	2.05	0.14
Bloomfield (1997)	3	36.07	30.20	1.13	11.64	0.38	5.25	1.55	0.00	2.04	0.15
Bloomfield (1997)	3	35.84	29.63	1.11	12.23	0.40	5.12	1.50	0.00	2.04	0.13
Bloomfield (1997)	3	35.80	30.36	1.56	12.40	0.91	3.61	1.18	0.00	2.20	0.00

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	3	35.99	29.07	1.80	12.82	0.68	0.00	1.35	0.91	2.04	0.08
Bloomfield (1997)	3	35.91	29.73	1.46	11.79	0.36	5.20	1.42	0.00	2.02	0.07
Bloomfield (1997)	3	35.82	30.30	0.65	12.22	0.30	5.20	1.48	0.00	2.11	0.15
Bloomfield (1997)	3	36.18	29.65	1.07	11.51	0.23	5.74	1.54	0.00	2.07	0.13
Bloomfield (1997)	3	35.83	28.65	1.73	12.40	0.40	5.11	1.66	0.00	1.98	0.00
Bloomfield (1997)	3	35.89	29.55	1.34	11.78	0.19	5.77	1.58	0.00	2.00	0.10
Bloomfield (1997)	3	35.68	29.39	1.44	12.13	0.24	5.51	1.52	0.00	1.97	0.23
Bloomfield (1997)	3	35.75	29.56	1.37	12.52	0.25	4.59	1.40	0.00	2.06	0.07
Bloomfield (1997)	3	36.43	32.68	1.17	9.73	0.51	3.84	1.08	0.00	2.00	0.08
Bloomfield (1997)	3	37.12	36.58	0.73	6.43	0.21	2.57	0.74	0.00	2.05	0.09
Bloomfield (1997)	3	37.81	39.47	0.52	3.76	0.22	1.36	1.18	1.56	1.83	0.00
Bloomfield (1997)	3	37.89	39.77	0.30	3.53	0.18	0.82	1.30	1.58	1.81	0.24
Bloomfield (1997)	3	37.88	41.31	0.16	1.24	0.30	0.25	1.58	1.79	1.58	0.30
Bloomfield (1997)	3	37.16	37.05	1.11	4.89	0.28	2.91	1.17	0.00	1.88	0.15
Bloomfield (1997)	3	37.15	36.33	1.19	5.68	0.17	2.84	0.80	0.00	2.00	0.10
Bloomfield (1997)	3	37.57	38.47	0.65	4.07	0.21	1.64	0.96	1.60	1.91	0.22
Bloomfield (1997)	3	36.91	41.94	0.19	1.13	0.29	0.27	1.92	1.61	1.50	0.35
Bloomfield (1997)	3	38.19	40.70	0.14	1.27	0.30	0.25	1.57	1.89	1.69	0.24
Bloomfield (1997)	3	37.05	40.70	0.00	1.20	0.20	0.16	1.74	1.78	1.50	0.32
Bloomfield (1997)	3	35.34	28.61	2.02	13.91	0.57	4.12	1.56	0.00	2.02	0.07
Bloomfield (1997)	3	35.55	28.60	1.95	13.94	0.56	4.19	1.61	0.00	1.98	0.08
Bloomfield (1997)	3	35.92	31.21	1.72	11.78	0.52	3.68	1.39	0.00	2.09	0.00
Bloomfield (1997)	3	37.28	34.20	1.61	7.97	0.13	2.88	0.66	0.00	2.17	0.00
Bloomfield (1997)	3	35.05	33.14	1.69	6.70	0.24	2.97	1.10	0.00	1.87	0.19
Bloomfield (1997)	3	36.58	34.84	1.92	7.44	0.38	2.46	0.79	0.00	2.07	0.20
Bloomfield (1997)	3	37.56	38.59	0.36	4.37	0.25	1.21	1.02	1.53	1.96	0.19
Bloomfield (1997)	3	36.48	37.38	0.15	7.29	0.68	0.75	0.91	0.95	2.01	0.22
Bloomfield (1997)	3	36.93	38.54	0.23	5.22	0.40	0.77	1.01	1.28	1.92	0.23

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	3	36.86	38.43	0.09	6.58	0.62	0.64	0.94	1.00	1.97	0.23
Bloomfield (1997)	3	36.98	41.19	0.19	1.52	0.23	0.36	1.74	1.65	1.57	0.31
Bloomfield (1997)	3	37.39	41.65	0.07	1.06	0.30	0.21	1.95	1.72	1.45	0.24
Bloomfield (1997)	3	37.90	40.12	0.22	2.29	0.35	0.89	1.79	1.74	1.42	0.12
Bloomfield (1997)	3	35.73	29.49	1.36	12.15	0.19	5.67	1.66	0.00	1.98	0.16
Bloomfield (1997)	3	35.65	29.45	1.24	11.82	0.21	5.77	1.55	0.00	2.05	0.09
Bloomfield (1997)	3	36.82	31.29	1.86	9.47	0.22	4.78	0.88	0.00	2.09	0.04
Bloomfield (1997)	3	35.40	29.95	1.63	10.37	0.24	3.72	0.94	0.00	2.02	0.00
Bloomfield (1997)	3	36.53	31.83	1.80	8.87	0.20	3.72	0.79	0.00	2.14	0.11
Bloomfield (1997)	3	35.99	33.73	1.83	8.21	0.42	2.79	0.71	0.00	2.13	0.13
Bloomfield (1997)	3	36.85	37.17	1.04	6.12	0.59	1.24	0.96	1.24	1.93	0.13
Bloomfield (1997)	3	37.36	39.47	0.18	3.66	0.29	0.78	1.34	1.51	1.78	0.21
Bloomfield (1997)	3	37.19	38.56	0.58	4.34	0.41	1.03	1.21	1.46	1.87	0.28
Bloomfield (1997)	3	37.52	41.44	0.19	1.69	0.31	0.31	1.55	1.64	1.60	0.14
Bloomfield (1997)	3	37.16	39.56	0.26	3.59	0.25	0.69	1.31	1.50	1.80	0.09
Bloomfield (1997)	3	35.63	29.67	1.68	12.64	0.38	4.77	1.47	0.00	2.10	0.16
Bloomfield (1997)	3	36.96	32.76	1.89	7.95	0.36	4.69	0.50	0.00	2.42	0.12
Bloomfield (1997)	3	37.08	41.24	0.18	1.27	0.21	1.03	1.55	1.70	1.54	0.18
Bloomfield (1997)	3	37.33	41.72	0.10	1.28	0.22	0.96	1.31	1.67	1.63	0.10
Bloomfield (1997)	3	37.37	41.81	0.08	1.19	0.20	1.02	1.37	1.69	1.62	0.20
Bloomfield (1997)	3	37.09	41.60	0.06	1.14	0.23	0.97	1.52	1.68	1.53	0.11
Bloomfield (1997)	3	37.20	41.64	0.00	1.17	0.21	0.92	1.54	1.69	1.55	0.13
Bloomfield (1997)	3	37.37	41.26	0.28	1.95	0.28	0.43	1.59	1.60	1.58	0.21
Bloomfield (1997)	3	37.18	40.18	0.21	2.89	0.19	0.58	1.54	1.56	1.64	0.19
Bloomfield (1997)	3	37.55	41.08	0.09	1.88	0.29	0.26	1.67	1.66	1.64	0.35
Bloomfield (1997)	3	36.79	42.16	0.13	1.03	0.23	0.10	1.92	1.60	1.48	0.24
Bloomfield (1997)	5	36.52	31.68	0.32	0.55	0.00	10.96	1.75	0.00	1.89	0.21
Bloomfield (1997)	5	36.90	31.44	0.21	0.60	0.00	11.07	1.74	0.00	1.99	0.09

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Bloomfield (1997)	5	37.10	31.68	0.26	0.56	0.00	11.01	1.63	0.00	2.09	0.00
Bloomfield (1997)	5	36.78	31.36	0.33	0.62	0.00	11.22	1.76	0.00	2.00	0.22
Bloomfield (1997)	5	36.78	31.36	0.33	0.62	0.00	11.22	1.76	0.00	2.00	0.22
Bloomfield (1997)	5	37.07	29.72	0.75	0.80	0.00	12.22	2.37	0.00	1.76	0.27
Bloomfield (1997)	5	37.01	29.57	0.97	0.94	0.00	12.29	2.44	0.00	1.67	0.30
Bloomfield (1997)	5	37.70	29.62	1.06	0.80	0.00	12.15	2.26	0.00	1.71	0.39
Bloomfield (1997)	5	36.95	30.15	0.53	0.77	0.00	11.88	2.23	0.00	1.79	0.29
Bloomfield (1997)	5	37.05	30.59	0.65	0.69	0.00	11.64	2.25	0.00	1.73	0.27
Bloomfield (1997)	5	37.14	29.98	0.60	0.86	0.04	11.99	2.28	0.00	1.81	0.34
Bloomfield (1997)	5	37.84	32.22	0.11	0.53	0.00	11.06	0.86	0.00	2.31	0.07
Bowman (1902)	2	36.96	39.56	0.03	2.14	2.00	0.15	1.28	1.64	2.10	1.13
Breaks (2008)	2	38.45	40.37	0.00	2.13	0.45	0.03	0.40	1.79	2.06	1.22
Breaks (2008)	2	38.51	39.97	0.00	2.41	0.42	0.04	0.38	1.80	2.15	1.20
Breaks (2008)	2	37.64	39.81	0.00	3.27	0.37	0.17	0.27	1.56	2.23	0.79
Breaks (2008)	2	38.28	39.33	0.00	2.57	0.39	0.05	0.41	1.82	2.09	1.08
Breaks (2008)	2	38.11	40.71	0.01	1.50	0.22	0.03	0.91	1.85	1.80	1.03
Breaks (2008)	2	38.19	40.69	0.01	1.58	0.20	0.02	1.04	1.85	1.78	1.02
Breaks (2008)	2	37.85	40.16	0.01	3.16	0.48	0.06	0.36	1.55	2.24	0.97
Breaks (2008)	2	38.22	39.60	0.01	3.46	0.41	0.10	0.14	1.62	2.31	1.15
Breaks (2008)	2	37.89	40.00	0.00	3.49	0.36	0.11	0.21	1.54	2.21	0.78
Breaks (2008)	2	38.16	35.86	0.29	3.81	0.02	3.70	0.12	0.00	2.82	1.50
Breaks (2008)	2	37.77	34.82	0.19	4.97	0.03	3.91	0.11	0.00	2.72	1.24
Breaks (2008)	2	38.46	37.56	0.09	2.32	0.04	2.17	0.20	0.00	2.59	1.67
Breaks (2008)	2	38.34	37.00	0.25	2.50	0.02	3.05	0.13	0.00	2.73	1.26
Breaks (2008)	2	37.61	34.68	0.46	4.37	0.00	4.69	0.07	0.00	2.83	1.56
Breaks (2008)	2	37.79	33.95	0.54	4.34	0.01	4.74	0.18	0.00	2.73	1.40
Breaks (2008)	2	38.39	37.84	0.20	2.27	0.04	2.14	0.19	0.00	2.62	1.29
Breaks (2008)	2	38.02	35.86	0.28	3.31	0.03	3.73	0.11	0.00	2.79	1.49

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	37.58	35.34	0.29	4.36	0.01	4.12	0.05	0.00	2.81	1.46
Breaks (2008)	2	37.89	36.55	0.20	3.26	0.01	3.65	0.06	0.00	2.80	1.32
Breaks (2008)	2	39.51	41.20	0.02	0.18	0.05	0.00	0.13	2.23	1.84	0.93
Breaks (2008)	2	39.50	41.36	0.00	0.18	0.04	0.01	0.16	2.21	1.84	0.79
Breaks (2008)	2	39.64	41.59	0.01	0.17	0.03	0.01	0.10	2.20	1.81	0.97
Breaks (2008)	2	39.51	41.33	0.00	0.17	0.04	0.01	0.18	2.22	1.83	0.96
Breaks (2008)	2	38.03	43.10	0.00	0.01	0.01	0.00	0.01	1.85	1.61	0.46
Breaks (2008)	2	38.15	42.45	0.01	0.00	0.00	0.00	0.02	1.95	1.63	0.60
Breaks (2008)	2	38.15	41.77	0.00	0.01	0.02	0.00	0.00	2.03	1.75	0.70
Breaks (2008)	2	38.11	42.62	0.00	0.01	0.01	0.00	0.00	1.92	1.62	0.52
Breaks (2008)	2	38.03	43.10	0.00	0.01	0.01	0.00	0.01	1.85	1.61	0.46
Breaks (2008)	2	38.15	42.45	0.01	0.00	0.00	0.00	0.02	1.95	1.63	0.60
Breaks (2008)	2	38.15	41.77	0.00	0.01	0.02	0.00	0.00	2.03	1.75	0.70
Breaks (2008)	2	38.11	42.62	0.00	0.01	0.01	0.00	0.00	1.92	1.62	0.52
Breaks (2008)	2	37.61	42.92	0.00	0.00	0.00	0.00	0.02	1.83	1.60	0.60
Breaks (2008)	2	37.64	42.84	0.00	0.00	0.01	0.00	0.01	1.84	1.72	0.65
Breaks (2008)	2	37.88	42.87	0.00	0.00	0.01	0.00	0.00	1.87	1.80	0.50
Breaks (2008)	2	37.74	42.01	0.00	0.01	0.00	0.00	0.06	1.95	1.85	0.75
Breaks (2008)	2	37.61	42.92	0.00	0.00	0.00	0.00	0.02	1.83	1.60	0.60
Breaks (2008)	2	38.42	42.37	0.00	0.01	0.00	0.00	0.01	1.99	1.90	0.94
Breaks (2008)	2	38.46	42.29	0.01	0.02	0.06	0.00	0.01	1.99	1.90	0.77
Breaks (2008)	2	38.57	42.71	0.00	0.01	0.04	0.00	0.02	1.96	1.81	0.80
Breaks (2008)	2	37.94	43.06	0.00	0.00	0.01	0.00	0.02	1.85	1.70	0.68
Breaks (2008)	2	37.79	42.86	0.00	0.01	0.00	0.00	0.01	1.85	1.62	0.77
Breaks (2008)	2	38.07	42.78	0.01	0.01	0.00	0.00	0.01	1.90	1.69	0.57
Breaks (2008)	2	37.62	42.61	0.00	0.00	0.00	0.00	0.07	1.86	1.87	0.97
Breaks (2008)	2	36.53	38.09	0.40	2.91	0.33	0.81	2.15	1.71	1.59	0.98
Breaks (2008)	2	37.39	42.66	0.00	0.29	0.07	0.01	0.60	1.77	1.76	0.86

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	37.89	42.53	0.00	0.22	0.06	0.00	0.37	1.86	1.79	0.76
Breaks (2008)	2	37.88	40.18	0.07	2.01	0.17	0.31	0.63	1.81	2.10	0.94
Breaks (2008)	2	37.78	42.79	0.00	0.01	0.01	0.00	0.02	1.86	1.84	0.55
Breaks (2008)	2	38.03	41.76	0.01	0.02	0.03	0.00	0.03	2.01	1.91	0.50
Breaks (2008)	2	37.92	42.14	0.00	0.05	0.13	0.01	0.02	1.93	1.83	0.72
Breaks (2008)	2	37.38	42.92	0.00	0.01	0.04	0.01	0.17	1.79	1.89	0.64
Breaks (2008)	2	38.41	42.56	0.00	0.01	0.03	0.00	0.02	1.96	1.84	0.85
Breaks (2008)	2	38.20	43.02	0.00	0.01	0.02	0.00	0.02	1.88	1.83	0.74
Breaks (2008)	2	37.53	43.19	0.00	0.01	0.04	0.00	0.01	1.78	1.71	0.62
Breaks (2008)	2	37.72	43.00	0.00	0.00	0.03	0.00	0.03	1.82	1.83	0.78
Breaks (2008)	2	38.07	42.59	0.00	0.01	0.04	0.00	0.03	1.92	1.81	0.48
Breaks (2008)	2	37.05	40.10	0.01	0.94	0.21	0.01	2.82	1.90	1.22	1.45
Breaks (2008)	2	36.74	40.82	0.00	1.28	0.23	0.02	2.00	1.71	1.45	0.93
Breaks (2008)	2	36.83	39.59	0.00	2.09	0.26	0.03	2.37	1.72	1.45	1.03
Breaks (2008)	2	36.59	38.99	0.00	3.30	0.29	0.06	2.10	1.54	1.60	1.41
Breaks (2008)	2	37.18	40.66	0.00	0.76	0.20	0.00	2.51	1.88	1.25	1.13
Breaks (2008)	2	36.05	39.75	0.00	3.06	0.38	0.04	1.72	1.41	1.73	0.93
Breaks (2008)	2	36.45	40.04	0.01	1.29	0.21	0.00	2.62	1.77	1.40	1.10
Breaks (2008)	2	35.75	39.76	0.00	3.65	0.37	0.06	1.78	1.27	1.69	1.01
Breaks (2008)	2	38.66	42.19	0.01	0.01	0.24	0.00	0.02	2.00	1.79	0.86
Breaks (2008)	2	38.78	41.68	0.00	0.01	0.22	0.00	0.09	2.08	1.67	0.70
Breaks (2008)	2	38.20	42.33	0.01	0.01	0.24	0.00	0.14	1.93	1.76	0.66
Breaks (2008)	2	38.19	41.79	0.01	0.00	0.77	0.00	0.41	1.91	1.87	0.76
Breaks (2008)	2	38.08	42.28	0.00	0.00	0.24	0.00	0.20	1.92	1.76	0.86
Breaks (2008)	2	37.76	42.46	0.00	0.00	0.27	0.00	0.04	1.86	1.85	0.69
Breaks (2008)	2	37.81	41.87	0.00	0.02	0.25	0.00	0.23	1.93	1.73	0.54
Breaks (2008)	2	37.68	42.19	0.00	0.00	0.23	0.00	0.15	1.89	1.84	0.88
Breaks (2008)	2	37.75	41.78	0.02	0.00	0.60	0.00	0.37	1.88	1.85	1.02

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	38.95	41.53	0.02	0.00	0.30	0.00	0.05	2.11	1.87	0.86
Breaks (2008)	2	38.03	42.77	0.00	0.00	0.15	0.00	0.03	1.87	1.71	0.88
Breaks (2008)	2	37.67	42.17	0.00	0.01	0.14	0.00	0.05	1.90	1.77	0.50
Breaks (2008)	2	38.34	42.33	0.00	0.00	0.14	0.00	0.23	1.97	1.65	0.50
Breaks (2008)	2	38.22	42.56	0.00	0.00	0.15	0.00	0.04	1.92	1.97	0.43
Breaks (2008)	2	38.71	42.63	0.00	0.00	0.14	0.00	0.05	1.98	1.69	0.69
Breaks (2008)	2	38.81	42.61	0.01	0.00	0.16	0.00	0.05	1.99	1.70	0.77
Breaks (2008)	2	39.03	42.51	0.00	0.00	0.13	0.00	0.04	2.03	1.64	0.71
Breaks (2008)	2	38.99	42.71	0.01	0.00	0.13	0.00	0.05	2.00	1.86	0.71
Breaks (2008)	2	38.60	42.68	0.02	0.00	0.25	0.00	0.04	1.94	1.74	1.05
Breaks (2008)	2	38.26	43.03	0.00	0.01	0.26	0.00	0.03	1.85	1.95	0.73
Breaks (2008)	2	38.20	42.62	0.00	0.00	0.25	0.00	0.04	1.90	2.01	0.51
Breaks (2008)	2	38.51	42.50	0.01	0.00	0.24	0.00	0.04	1.95	1.73	0.82
Breaks (2008)	2	38.40	42.59	0.02	0.00	0.23	0.01	0.04	1.93	1.96	0.43
Breaks (2008)	2	38.18	42.54	0.00	0.00	0.24	0.00	0.05	1.91	1.79	0.80
Breaks (2008)	2	38.78	41.83	0.00	0.00	0.23	0.01	0.04	2.07	1.79	0.50
Breaks (2008)	2	38.68	42.76	0.00	0.00	0.24	0.00	0.05	1.94	1.82	0.59
Breaks (2008)	2	38.70	42.80	0.00	0.00	0.24	0.00	0.04	1.94	1.96	0.78
Breaks (2008)	2	38.31	42.60	0.02	0.00	0.48	0.00	0.04	1.87	1.81	0.71
Breaks (2008)	2	37.39	42.07	0.00	0.01	0.93	0.00	0.42	1.75	1.84	1.06
Breaks (2008)	2	37.78	43.00	0.01	0.00	0.27	0.00	0.02	1.79	1.68	0.55
Breaks (2008)	2	38.39	42.93	0.00	0.01	0.28	0.00	0.02	1.88	1.62	0.57
Breaks (2008)	2	38.32	43.40	0.00	0.00	0.29	0.00	0.04	1.81	1.65	0.38
Breaks (2008)	2	38.30	43.47	0.00	0.01	0.27	0.00	0.02	1.80	1.70	0.60
Breaks (2008)	2	38.14	43.44	0.00	0.00	0.29	0.00	0.03	1.78	1.63	0.48
Breaks (2008)	2	38.47	43.16	0.00	0.00	0.27	0.00	0.02	1.86	1.70	0.57
Breaks (2008)	2	37.80	43.07	0.00	0.00	0.28	0.00	0.02	1.79	1.62	0.20
Breaks (2008)	2	37.98	43.20	0.01	0.00	0.26	0.00	0.01	1.80	1.69	0.43

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	37.65	43.13	0.00	0.00	0.38	0.00	0.04	1.75	1.73	0.50
Breaks (2008)	2	37.68	43.16	0.00	0.00	0.41	0.00	0.03	1.74	1.72	0.29
Breaks (2008)	2	36.77	41.63	0.00	0.01	0.88	0.00	0.47	1.73	1.85	0.76
Breaks (2008)	2	37.72	41.95	0.00	0.01	0.75	0.00	0.43	1.83	1.87	0.58
Breaks (2008)	2	38.07	43.72	0.00	0.00	0.27	0.00	0.02	1.74	1.71	0.69
Breaks (2008)	2	37.54	41.99	0.01	0.01	0.52	0.00	0.03	1.84	1.79	0.76
Breaks (2008)	2	38.16	42.79	0.01	0.00	0.45	0.00	0.09	1.84	1.72	0.89
Breaks (2008)	2	37.06	41.24	0.00	0.00	1.20	0.00	0.41	1.77	1.85	0.75
Breaks (2008)	2	38.52	40.72	0.00	0.00	1.09	0.00	0.59	2.03	1.79	1.15
Breaks (2008)	2	36.53	41.60	0.02	0.01	1.30	0.00	0.32	1.64	1.91	1.38
Breaks (2008)	2	36.57	41.36	0.00	0.01	1.28	0.00	0.35	1.68	1.87	1.34
Breaks (2008)	2	38.12	42.42	0.00	0.01	0.24	0.00	0.28	1.91	1.75	1.03
Breaks (2008)	2	37.94	42.15	0.01	0.01	0.35	0.00	0.42	1.90	1.83	0.98
Breaks (2008)	2	38.13	42.22	0.00	0.00	0.28	0.00	0.29	1.93	1.86	1.07
Breaks (2008)	2	37.33	41.62	0.00	0.01	0.32	0.00	0.34	1.90	1.83	0.88
Breaks (2008)	2	37.51	42.02	0.02	0.00	0.81	0.00	0.35	1.79	1.86	0.97
Breaks (2008)	2	38.06	41.89	0.00	0.01	1.00	0.00	0.51	1.84	1.86	1.13
Breaks (2008)	2	38.64	41.61	0.01	0.00	0.66	0.00	0.05	2.01	1.91	0.90
Breaks (2008)	2	38.01	42.16	0.02	0.00	0.67	0.00	0.06	1.86	1.93	0.96
Breaks (2008)	2	37.72	39.83	0.01	0.10	2.13	0.00	0.50	1.85	2.03	0.90
Breaks (2008)	2	37.60	41.71	0.01	0.01	0.95	0.00	0.47	1.82	1.88	0.97
Breaks (2008)	2	38.11	41.51	0.01	0.00	1.21	0.00	0.32	1.86	1.84	1.25
Breaks (2008)	2	39.25	40.94	0.00	0.00	0.35	0.00	0.03	2.21	1.78	0.57
Breaks (2008)	2	39.05	41.28	0.00	0.01	0.35	0.00	0.05	2.15	1.72	0.59
Breaks (2008)	2	38.92	42.00	0.01	0.02	0.31	0.00	0.07	2.05	1.96	0.19
Breaks (2008)	2	38.63	42.16	0.00	0.00	0.32	0.00	0.06	1.99	1.94	0.35
Breaks (2008)	2	38.52	41.06	0.01	0.00	0.61	0.00	0.27	2.07	1.85	0.52
Breaks (2008)	2	38.53	40.59	0.00	0.01	0.68	0.00	0.23	2.11	1.78	0.63

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	38.73	40.94	0.01	0.00	1.34	0.00	0.44	1.99	1.92	1.10
Breaks (2008)	2	38.47	40.22	0.03	0.01	1.60	0.00	0.44	2.00	1.94	1.00
Breaks (2008)	2	38.30	40.14	0.00	0.01	1.55	0.00	0.46	2.00	1.96	1.01
Breaks (2008)	2	38.55	40.26	0.01	0.01	1.74	0.00	0.32	1.98	2.09	0.92
Breaks (2008)	2	38.71	40.24	0.02	0.00	1.11	0.00	0.64	2.11	1.84	0.99
Breaks (2008)	2	38.44	39.90	0.02	0.00	1.41	0.00	0.40	2.07	1.95	1.16
Breaks (2008)	2	38.55	40.52	0.00	0.02	1.19	0.00	0.60	2.04	1.83	1.12
Breaks (2008)	2	38.64	40.65	0.01	0.00	1.56	0.00	0.44	1.98	1.98	1.10
Breaks (2008)	2	38.96	39.71	0.00	0.00	1.28	0.00	0.11	2.17	2.01	0.84
Breaks (2008)	2	37.96	38.90	0.03	2.62	1.66	0.22	0.27	1.62	2.44	1.62
Breaks (2008)	2	38.16	38.65	0.03	2.76	1.63	0.23	0.24	1.66	2.38	1.24
Breaks (2008)	2	38.06	38.66	0.02	2.68	1.72	0.22	0.28	1.64	2.42	1.31
Breaks (2008)	2	37.75	38.42	0.02	2.93	1.86	0.24	0.24	1.56	2.51	1.27
Breaks (2008)	2	38.15	38.19	0.04	2.97	1.81	0.26	0.20	1.64	2.38	1.32
Breaks (2008)	2	38.09	38.05	0.04	3.03	1.85	0.24	0.25	1.64	2.49	1.50
Breaks (2008)	2	38.03	37.99	0.02	2.89	1.93	0.21	0.23	1.65	2.46	1.42
Breaks (2008)	2	37.72	38.56	0.03	3.03	1.82	0.20	0.24	1.53	2.48	1.24
Breaks (2008)	2	37.57	38.24	0.04	3.16	1.76	0.28	0.21	1.54	2.49	1.35
Breaks (2008)	2	37.94	38.55	0.03	2.89	1.76	0.24	0.21	1.60	2.45	1.50
Breaks (2008)	2	39.31	41.21	0.00	0.00	0.27	0.01	0.39	2.20	1.72	1.10
Breaks (2008)	2	39.68	41.39	0.00	0.00	0.24	0.00	0.33	2.23	1.77	1.34
Breaks (2008)	2	34.77	31.17	0.46	10.45	0.10	4.37	1.62	0.00	1.87	1.14
Breaks (2008)	2	35.24	29.92	0.48	10.16	0.06	6.09	1.78	0.00	1.81	1.02
Breaks (2008)	2	34.92	31.72	0.44	12.47	0.12	3.12	0.74	0.00	2.06	0.51
Breaks (2008)	2	34.83	31.01	0.54	11.53	0.15	4.16	1.52	0.00	1.94	0.49
Breaks (2008)	2	35.25	32.35	0.23	12.80	0.08	2.67	0.36	0.00	2.12	0.07
Breaks (2008)	2	35.12	31.35	0.28	10.57	0.14	4.75	1.46	0.00	2.06	0.67
Breaks (2008)	2	35.41	30.78	0.51	10.20	0.15	4.40	1.54	0.00	1.88	0.69

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Breaks (2008)	2	38.20	39.94	0.00	0.15	0.11	0.02	2.77	2.22	1.08	1.41
Breaks (2008)	2	37.93	41.62	0.00	0.13	0.10	0.00	2.17	1.98	1.18	1.16
Breaks (2008)	2	36.81	40.49	0.00	0.32	0.15	0.00	3.12	1.94	1.06	1.13
Breaks (2008)	2	37.18	39.53	0.00	0.89	0.16	0.00	3.46	2.00	0.96	1.28
Breaks (2008)	2	36.76	39.49	0.00	2.59	0.33	0.05	1.48	1.62	1.73	1.00
Breaks (2008)	2	36.79	38.82	0.00	3.08	0.35	0.08	1.80	1.61	1.71	0.79
Breaks (2008)	2	37.95	39.62	0.00	0.76	0.21	0.01	3.15	2.10	1.06	1.42
Breaks (2008)	2	37.45	40.67	0.00	0.11	0.13	0.00	3.26	2.04	0.98	1.06
Breaks (2008)	2	37.16	39.82	0.00	1.90	0.34	0.02	2.50	1.75	1.40	0.99
Cavarretta (1990)	8	35.01	36.38	0.77	8.37	0.19	3.16	0.26	0.00	1.70	0.00
Cavarretta (1990)	8	34.94	36.37	0.75	9.22	0.21	3.08	0.26	0.00	1.76	0.00
Cavarretta (1990)	8	34.33	36.91	0.77	9.37	0.37	3.39	0.26	0.00	2.16	0.00
Cavarretta (1990)	8	35.09	35.55	0.78	9.30	0.31	3.61	0.24	0.00	1.89	0.00
Cavarretta (1990)	8	34.49	33.58	1.28	8.59	0.29	4.36	0.25	0.00	2.31	0.00
Cavarretta (1990)	8	34.49	34.24	0.92	7.82	0.22	4.57	0.21	0.00	2.19	0.00
Cavarretta (1990)	8	37.11	34.47	0.79	7.05	0.20	5.34	0.39	0.00	1.73	0.00
Cavarretta (1990)	8	35.29	34.72	1.03	5.67	0.16	6.67	0.36	0.00	2.45	0.00
Cavarretta (1990)	8	35.65	34.87	0.97	5.13	0.08	6.05	0.37	0.00	2.09	0.00
Cavarretta (1990)	8	36.08	34.61	0.87	4.79	0.16	6.51	0.29	0.00	1.97	0.00
Cavarretta (1990)	8	35.65	34.45	1.21	6.27	0.13	6.77	0.39	0.00	2.21	0.00
Cavarretta (1990)	8	37.35	32.83	1.25	5.39	0.04	6.96	0.48	0.00	2.17	0.00
Cavarretta (1990)	8	35.72	32.97	1.46	5.68	0.08	6.89	0.54	0.00	2.06	0.00
Cavarretta (1990)	8	36.66	33.06	0.80	5.65	0.00	7.23	0.55	0.00	2.00	0.00
Cavarretta (1990)	8	35.59	32.19	1.60	5.86	0.12	7.30	0.61	0.00	2.42	0.00
Cavarretta (1990)	8	35.47	33.91	1.29	4.71	0.10	7.53	0.48	0.00	2.16	0.00
Cavarretta (1990)	8	36.47	32.63	0.84	5.00	0.12	7.62	0.58	0.00	1.71	0.00
Cavarretta (1990)	8	35.60	29.82	0.23	9.91	0.00	6.81	1.28	0.00	2.17	0.00
Cavarretta (1990)	8	35.70	31.05	0.00	12.64	0.00	4.85	0.96	0.00	2.03	0.00

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Cavarretta (1990)	8	34.26	19.79	0.00	23.39	0.00	4.98	0.69	0.00	2.41	0.00
Cavarretta (1990)	8	34.09	19.85	0.00	25.31	0.00	4.45	1.11	0.00	2.25	0.00
Cavarretta (1990)	8	30.60	19.32	0.17	24.88	0.20	4.62	0.96	0.00	2.22	0.00
Cavarretta (1990)	8	33.65	15.09	0.10	29.47	0.15	5.71	0.74	0.00	2.54	0.00
Cavarretta (1990)	8	35.15	31.00	0.25	9.69	0.00	5.65	0.90	0.00	2.30	0.00
Cavarretta (1990)	8	35.31	29.79	0.27	10.89	0.00	5.65	0.90	0.00	2.30	0.00
Cavarretta (1990)	8	34.90	30.16	0.37	12.05	0.28	5.54	1.06	0.00	1.97	0.00
Cavarretta (1990)	8	36.46	30.90	0.20	8.96	0.00	6.52	1.29	0.00	2.20	0.00
Cavarretta (1990)	8	36.04	32.14	0.00	9.69	0.00	5.24	0.96	0.00	1.95	0.00
Cavarretta (1990)	8	36.32	32.10	0.51	8.36	0.00	5.64	0.98	0.00	1.65	0.00
Cavarretta (1990)	8	36.48	32.67	0.30	8.39	0.00	5.68	0.86	0.00	2.13	0.00
Cavarretta (1990)	8	35.79	31.86	0.18	9.03	0.00	5.74	0.95	0.00	2.10	0.00
Cavarretta (1990)	8	35.21	29.95	0.00	8.98	0.07	6.87	0.62	0.00	2.61	0.00
Cavarretta (1990)	8	35.67	30.88	0.00	8.63	0.14	6.31	0.74	0.00	2.28	0.00
Cavarretta (1990)	8	35.10	30.85	0.00	8.06	0.06	6.90	0.94	0.00	2.37	0.00
Cempirek et al (2006)	1	33.56	43.44	0.07	5.70	0.38	0.40	0.69	0.19	1.63	0.02
Chaudhry and Howie (1976)	2	37.08	41.72	0.08	1.12	0.00	0.21	1.80	1.19	2.61	0.00
Chaudhry and Howie (1976)	2	37.52	42.43	0.12	1.26	0.00	0.37	0.32	1.34	2.27	0.00
Chaudhry and Howie (1976)	2	37.14	44.24	0.00	0.06	0.00	0.33	0.32	1.52	2.50	0.00
Chaudhry and Howie (1976)	2	36.86	43.59	0.12	0.27	0.27	0.51	0.68	1.33	2.27	0.00
Chaudhry and Howie (1976)	2	36.86	35.49	0.00	6.46	0.30	0.35	2.51	1.12	2.61	0.00
Chaudhry and Howie (1976)	2	36.64	37.43	0.38	7.17	0.06	0.31	0.36	1.17	2.40	0.00
Chaudhry and Howie (1976)	2	36.36	40.48	0.00	3.64	1.05	0.09	0.67	1.27	2.20	0.00
Deer, Howie and Zussman (1962)	2	38.10	38.50	0.09	3.87	0.46	0.10	0.10	1.52	2.93	0.77
Deer, Howie and Zussman (1962)	2	37.88	38.75	0.02	3.63	0.63	0.69	0.70	1.44	2.07	1.16
Donnay and Barton (1972)	2	37.46	40.36	0.00	0.22	2.08	0.00	0.82	1.94	1.82	1.19
Donnay et al (1966)	8	33.86	30.79	0.55	17.12	0.13	0.13	0.69	0.00	2.46	1.86

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Dyar et al (1998)	1	34.51	32.45	1.03	13.61	0.21	1.96	0.26	0.09	1.98	0.56
Dyar et al (1998)	1	35.37	33.93	0.66	7.78	0.04	4.83	0.53	0.01	1.87	0.18
Dyar et al (1998)	1	35.46	33.71	0.12	10.81	0.11	2.49	0.13	0.01	1.71	0.38
Dyar et al (1998)	1	35.47	33.75	0.15	12.10	0.12	1.61	0.09	0.02	1.66	0.33
Dyar et al (1998)	1	35.45	33.83	0.31	10.96	0.13	2.71	0.12	0.01	1.84	0.26
Dyar et al (1998)	1	33.47	32.08	0.48	16.05	0.16	0.24	0.47	0.04	1.98	1.08
Dyar et al (1998)	1	33.27	33.29	0.71	14.48	1.10	0.20	0.15	0.11	2.08	0.30
Dyar et al (1998)	1	35.04	33.82	0.36	12.62	0.20	1.70	0.13	0.09	1.76	0.51
Dyar et al (1998)	2	36.53	37.11	0.01	6.98	0.29	0.00	0.09	1.31	2.41	1.37
Dyar et al (1998)	2	36.56	36.73	0.02	8.76	0.14	0.66	0.05	1.04	2.23	1.13
Dyar et al (1998)	2	36.57	36.72	0.05	6.74	0.37	0.01	0.10	1.60	2.58	1.51
Dyar et al (1998)	2	36.34	36.94	0.03	7.71	0.23	0.00	0.09	1.28	2.03	1.08
Dyar et al (1998)	2	36.28	37.66	0.02	6.83	0.49	0.02	0.09	1.39	2.17	1.13
Dyar et al (1998)	2	37.77	43.90	0.02	0.01	0.44	0.01	0.02	1.54	1.51	0.57
Dyar et al (1998)	2	37.99	42.84	0.02	0.00	0.41	0.00	0.06	1.86	1.58	0.95
Dyar et al (1998)	2	38.36	42.27	0.02	0.00	0.27	0.00	0.36	2.35	1.59	1.11
Dyar et al (1998)	2	36.58	38356.00	0.04	4.94	0.63	0.01	0.25	1.67	2.38	1.54
Dyar et al (1998)	4	36.64	32.84	0.93	5.14	0.05	7.32	0.42	0.03	1.93	0.58
Dyar et al (1998)	4	36.13	33.59	0.56	5.94	0.04	5.54	0.84	0.00	1.17	0.11
Dyar et al (1998)	4	37.52	31.87	1.02	0.46	0.01	11.28	0.46	0.00	2.23	0.24
Dyar et al (1998)	4	33.95	29.55	0.39	0.00	0.00	8.33	1.86	0.00	1.15	0.54
Dyar et al (1998)	5	37.38	30.56	0.03	0.00	0.00	13.92	2.99	0.00	1.21	1.22
Dyar et al (1998)	5	35.67	36.90	0.00	1.63	0.02	9.34	1.66	0.00	2.15	0.00
Dyar et al (1998)	6	36.53	32.27	0.26	2.27	0.01	10.42	2.06	0.02	1.45	0.20
Dyar et al (1998)	8	35.63	35.77	0.03	9.41	0.01	2.16	0.01	0.00	0.95	0.08
Dyar et al (1998)	8	33.43	31.37	0.57	0.00	0.11	0.16	0.33	0.02	2.36	1.52
Dyar et al (1998)	8	35.41	35.12	0.35	12.29	0.09	1.29	0.01	0.01	1.00	0.20
Ertl (2013)	4	36.92	33.55	0.74	3.04	0.00	8.99	0.58	0.00	2.27	0.06

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Ertl (2013)	4	37.22	34.11	0.82	3.04	0.00	8.36	0.64	0.00	2.05	0.06
Groat (2002)	6	37.42	28.23	0.28	6.95	0.00	9.76	2.78	0.00	1.63	0.25
Groat (2002)	6	34.59	30.96	1.56	10.69	0.31	4.80	0.75	0.00	2.16	0.91
Groat (2002)	6	35.69	32.73	0.44	5.18	0.02	8.40	1.29	0.00	1.70	0.02
Groat (2002)	8	36.11	29.32	0.21	3.48	0.02	12.17	3.01	0.00	1.26	0.76
Groat (2002)	8	35.72	33.75	0.31	4.83	0.00	7.95	1.53	0.00	1.19	0.19
Henry PhD	4	36.81	33.59	0.76	5.10	0.00	7.07	0.61	0.00	1.94	0.23
Henry PhD	4	36.62	33.89	0.84	5.05	0.00	7.12	0.62	0.00	1.93	0.31
Henry PhD	4	36.55	33.22	0.74	6.10	0.01	6.91	0.48	0.00	2.01	0.16
Henry PhD	4	36.41	33.27	0.72	5.80	0.01	7.26	0.60	0.00	1.92	0.11
Henry PhD	4	36.10	33.04	0.69	6.92	0.00	6.49	0.49	0.00	1.95	0.30
Henry PhD	4	36.60	33.70	0.75	6.68	0.00	6.28	0.49	0.00	2.06	0.22
Henry PhD	4	36.48	33.60	0.77	7.17	0.00	6.32	0.52	0.00	2.01	0.26
Henry PhD	4	36.20	32.72	0.83	6.85	0.01	6.41	0.64	0.00	1.95	0.22
Henry PhD	4	36.44	32.93	0.72	7.00	0.01	6.83	0.32	0.00	2.25	0.17
Henry PhD	4	36.74	33.29	0.77	6.99	0.00	6.32	0.51	0.00	1.96	0.17
Henry PhD	4	36.14	33.56	0.31	7.98	0.03	5.83	0.08	0.00	2.08	0.13
Henry PhD	4	36.59	33.77	0.72	5.82	0.01	7.02	0.56	0.00	2.01	0.13
Henry PhD	4	36.68	32.96	0.71	6.77	0.00	6.68	0.62	0.00	1.95	0.17
Henry PhD	4	36.44	33.13	0.81	6.92	0.00	6.38	0.63	0.00	1.97	0.16
Henry PhD	4	35.89	31.26	0.87	6.86	0.00	7.73	0.43	0.00	2.16	0.20
Henry PhD	4	36.57	32.43	0.81	7.67	0.02	6.43	0.19	0.00	2.30	0.12
Henry PhD	4	35.56	29.09	0.68	7.63	0.01	8.71	0.93	0.00	1.91	0.49
Henry PhD	4	37.92	33.75	0.53	5.51	0.01	6.56	0.19	0.00	1.90	0.09
Henry PhD	4	36.51	33.13	0.70	6.27	0.00	7.07	0.55	0.00	2.13	0.17
Henry PhD	4	37.32	33.97	0.68	5.89	0.01	7.07	0.52	0.00	2.05	0.14
Henry PhD	4	36.68	32.55	0.76	5.95	0.02	6.61	0.44	0.00	2.02	0.03
Henry PhD	4	36.28	32.50	0.78	7.51	0.02	6.53	0.55	0.00	2.06	0.14

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Henry PhD	4	36.57	34.10	0.68	5.62	0.01	6.77	0.42	0.00	2.00	0.12
Henry PhD	4	36.17	33.81	0.74	6.40	0.04	6.76	0.63	0.00	1.88	0.16
Henry PhD	4	36.13	33.52	0.76	5.67	0.02	7.00	0.54	0.00	1.96	0.16
Henry PhD	4	36.45	32.61	0.70	6.05	0.03	6.60	0.52	0.00	1.99	0.16
Henry PhD	4	36.20	33.02	0.74	6.32	0.01	6.67	0.50	0.00	1.98	0.14
Henry PhD	4	35.89	33.59	0.77	6.18	0.02	6.54	0.56	0.00	1.92	0.18
Henry PhD	4	36.52	33.16	0.79	6.36	0.00	6.71	0.44	0.00	2.01	0.19
Henry PhD	4	36.77	33.39	0.63	5.49	0.02	6.84	0.39	0.00	2.02	0.14
Henry PhD	4	36.38	32.86	0.78	5.12	0.04	7.14	0.39	0.00	2.04	0.00
Henry PhD	4	36.16	32.40	0.77	5.93	0.05	7.01	0.48	0.00	2.08	0.00
Henry PhD	4	36.35	33.00	0.79	4.95	0.05	7.13	0.38	0.00	2.04	0.00
Henry PhD	4	36.70	32.79	0.75	5.14	0.05	7.21	0.49	0.00	2.03	0.00
Henry PhD	4	36.81	33.59	0.76	5.10	0.00	7.07	0.61	0.00	1.94	0.23
Henry PhD	4	36.62	33.89	0.84	5.05	0.00	7.12	0.62	0.00	1.93	0.31
Henry PhD	4	36.44	33.13	0.81	6.92	0.00	6.38	0.63	0.00	1.97	0.16
Henry PhD	4	36.74	33.29	0.77	6.99	0.00	6.32	0.51	0.00	1.96	0.17
Henry PhD	4	36.13	33.52	0.76	5.67	0.02	7.00	0.54	0.00	1.96	0.16
Henry PhD	4	36.39	34.00	0.71	5.50	0.00	6.97	0.51	0.00	1.98	0.18
Henry PhD	4	36.51	31.97	0.82	6.13	0.04	7.13	0.86	0.00	1.98	0.18
Henry PhD	4	36.17	33.81	0.74	6.40	0.04	6.76	0.63	0.00	1.88	0.16
Henry PhD	4	36.52	33.16	0.79	6.36	0.00	6.71	0.44	0.00	2.01	0.19
Henry PhD	4	36.75	33.38	0.72	6.48	0.01	6.43	0.42	0.00	2.10	0.00
Henry PhD	4	36.88	33.30	0.77	6.54	0.01	6.66	0.43	0.00	2.10	0.00
Henry PhD	4	36.31	33.12	0.69	6.40	0.01	6.75	0.49	0.00	2.04	0.00
Henry PhD	4	36.63	33.50	0.75	5.86	0.01	6.89	0.45	0.00	2.07	0.00
Laurs 1996	1	36.30	32.27	0.69	10.86	0.07	5.06	0.58	0.00	2.38	1.02
Laurs 1996	1	36.28	32.71	0.64	12.85	0.19	3.22	0.32	0.00	2.46	0.98
Laurs 1996	1	36.36	31.54	0.71	10.36	0.09	5.13	0.54	0.00	2.46	1.36

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Laurs 1996	1	36.25	32.63	0.33	10.95	0.11	3.87	0.22	0.00	2.08	0.79
Laurs 1996	1	36.12	33.14	0.70	10.70	0.34	3.63	0.25	0.00	2.21	1.00
Laurs 1996	1	36.10	31.96	0.94	10.33	0.14	4.94	0.62	0.00	2.31	1.06
Laurs 1996	1	35.96	32.10	0.49	9.32	0.12	5.91	0.63	0.00	2.31	1.03
Laurs 1996	1	36.27	32.43	0.67	10.30	0.11	5.08	0.49	0.00	2.39	1.07
Laurs 1996	1	35.80	31.09	1.10	11.38	0.05	5.08	0.87	0.00	2.21	0.86
Laurs 1996	1	36.28	30.86	1.09	10.68	0.05	5.67	0.83	0.00	2.23	0.78
Laurs 1996	1	36.07	30.87	0.45	10.84	0.02	5.76	1.21	0.00	2.07	0.98
Laurs 1996	1	36.47	32.67	0.65	10.08	0.32	5.40	0.22	0.00	2.59	1.30
Laurs 1996	1	35.90	32.49	0.70	8.79	0.31	5.89	0.36	0.00	2.45	1.41
Laurs 1996	1	37.86	32.94	0.15	6.94	0.17	7.07	0.43	0.00	2.46	1.39
Laurs 1996	1	36.53	33.69	0.16	6.67	0.16	6.29	0.25	0.00	2.15	0.70
Laurs 1996	1	36.84	34.14	0.17	6.99	0.09	6.13	0.17	0.00	2.20	0.96
Laurs 1996	1	36.86	33.62	0.30	6.82	0.11	6.18	0.29	0.00	2.17	0.65
Laurs 1996	1	36.76	34.15	0.23	7.40	0.20	5.77	0.11	0.00	2.20	0.95
Laurs 1996	1	36.04	32.38	0.65	9.41	0.34	5.06	0.21	0.00	2.56	1.34
Laurs 1996	1	36.54	33.50	0.31	5.26	0.62	7.30	0.47	0.00	2.45	1.33
Laurs 1996	6	36.91	31.46	0.40	5.70	0.03	9.10	1.30	0.00	2.25	1.57
Laurs 1996	6	37.14	31.04	0.39	5.78	0.09	9.54	1.79	0.00	1.93	1.54
Laurs 1996	6	36.98	30.49	0.36	5.89	0.06	9.60	2.20	0.00	1.74	1.28
Laurs 1996	6	36.35	29.45	0.25	6.70	0.05	9.75	2.87	0.00	1.30	1.41
Laurs 1996	6	36.48	30.56	0.47	7.15	0.09	8.93	1.89	0.00	1.86	1.26
Laurs 1996	6	36.87	30.20	0.28	6.77	0.07	9.39	2.37	0.00	1.61	1.39
Laurs 1996	6	36.03	31.16	0.23	7.07	0.04	7.84	1.03	0.00	2.30	1.08
Laurs 1996	6	36.15	29.16	0.44	6.70	0.09	9.62	1.99	0.00	1.70	1.56
Laurs 1996	6	36.15	29.81	0.35	6.92	0.07	8.73	1.75	0.00	1.95	1.28
Laurs 1996	6	36.51	32.36	0.11	7.37	0.06	6.39	0.42	0.00	2.08	0.63
Laurs 1996	6	37.09	30.13	0.32	6.28	0.10	9.18	1.73	0.00	2.07	1.25

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Laurs 1996	6	37.19	29.92	0.29	6.49	0.08	9.42	1.88	0.00	1.87	1.18
Laurs 1996	6	37.82	31.67	0.18	3.64	0.02	10.31	2.15	0.00	1.76	0.17
Laurs 1996	6	37.83	31.51	0.17	3.55	0.01	10.41	2.26	0.00	1.67	0.15
Laurs 1996	6	37.49	31.85	0.18	3.42	0.00	10.13	2.27	0.00	1.66	0.13
Laurs 1996	6	38.08	32.09	0.16	3.29	0.05	10.44	2.30	0.00	1.66	0.15
Laurs 1996	6	37.21	33.10	0.12	2.95	0.01	9.94	2.04	0.00	1.83	0.13
Laurs 1996	6	37.80	33.95	0.02	2.95	0.01	9.52	1.72	0.00	1.93	0.10
Laurs 1996	6	37.28	32.66	0.30	6.71	0.26	7.38	0.35	0.00	2.65	1.36
Laurs 1996	6	36.86	32.78	0.65	9.75	0.61	4.43	0.21	0.00	2.49	1.41
Laurs 1996	6	36.82	32.26	0.78	9.07	0.50	5.14	0.23	0.00	2.48	1.33
Laurs 1996	6	36.68	31.43	0.57	8.63	0.24	6.16	0.31	0.00	2.48	1.18
Laurs 1996	6	36.56	31.98	0.57	8.59	0.25	6.29	0.30	0.00	2.59	1.23
Laurs 1996	6	36.86	32.22	0.57	7.76	0.30	6.49	0.33	0.00	2.59	1.31
Laurs 1996	6	36.53	31.75	0.64	8.67	0.23	6.31	0.35	0.00	2.53	1.34
Laurs 1996	6	37.05	32.19	0.40	5.88	0.18	8.08	0.43	0.00	2.49	1.38
Laurs 1996	6	37.36	31.57	0.47	4.91	0.27	9.14	0.46	0.00	2.65	1.61
Laurs 1996	6	37.29	32.46	0.34	7.61	0.37	5.81	0.20	0.00	2.53	1.53
Laurs 1996	6	36.23	33.11	0.37	10.43	0.24	4.22	0.11	0.00	2.14	0.98
Laurs 1996	6	35.96	31.58	0.68	10.25	0.27	4.88	0.30	0.00	2.50	1.28
Laurs 1996	6	36.63	31.97	0.70	8.05	0.42	6.02	0.39	0.00	2.42	1.39
Laurs 1996	6	36.27	31.39	1.09	8.82	0.43	6.16	0.79	0.00	2.24	1.09
Marschall 2006 (15 cation optimal)	1	34.52	34.18	0.61	11.91	0.21	2.25	0.21	0.00	1.93	0.60
Marschall 2006 (15 cation optimal)	1	34.33	33.97	0.51	12.42	0.16	2.46	0.23	0.00	2.02	0.66
Marschall 2006 (15 cation optimal)	1	34.49	34.39	0.41	11.82	0.19	2.72	0.23	0.00	1.94	0.63
Marschall 2006 (31 oxygen optimal)	6	36.10	31.26	0.12	5.13	0.00	9.21	0.10	0.00	3.08	0.04
Marschall 2006 (31 oxygen optimal)	6	35.75	30.39	0.56	6.85	0.00	8.53	0.27	0.00	3.04	0.04
Marschall 2006 (31 oxygen optimal)	6	35.57	29.53	1.14	9.17	0.00	7.21	0.25	0.00	2.92	0.03

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Marschall 2006 (31 oxygen optimal)	6	35.68	30.59	0.57	7.58	0.00	7.89	0.22	0.00	2.96	0.05
Marschall 2006 (31 oxygen optimal)	6	36.27	31.35	0.44	4.61	0.01	9.31	0.21	0.00	2.94	0.05
Marschall 2006 (31 oxygen optimal)	6	36.08	31.78	0.11	3.94	0.03	9.95	0.07	0.00	3.12	0.02
Marschall 2006 (31 oxygen optimal)	6	35.98	30.58	0.16	7.64	0.00	8.24	0.14	0.00	3.03	0.02
Marschall 2006 (31 oxygen optimal)	6	35.51	29.41	0.79	9.28	0.02	7.39	0.28	0.00	2.84	0.04
Marschall 2006 (31 oxygen optimal)	6	35.87	30.10	0.49	7.30	0.01	8.39	0.23	0.00	2.96	0.01
Marschall 2006 (31 oxygen optimal)	6	35.31	29.68	0.68	8.76	0.00	7.67	0.25	0.00	3.00	0.05
Marschall 2006 (31 oxygen optimal)	6	36.21	30.78	0.16	5.54	0.03	9.27	0.11	0.00	3.03	0.00
Marschall 2006 (31 oxygen optimal)	6	35.85	30.00	0.59	6.78	0.04	8.84	0.24	0.00	2.96	0.06
Marschall 2006 (31 oxygen optimal)	6	36.25	31.41	0.12	4.60	0.03	9.73	0.09	0.00	3.03	0.00
Marschall 2006 (31 oxygen optimal)	6	36.18	30.31	0.75	5.99	0.03	9.25	0.28	0.00	2.96	0.03
Marschall 2006 (31 oxygen optimal)	6	36.48	31.17	0.48	4.97	0.00	9.28	0.26	0.00	2.97	0.02
Marschall 2006 (31 oxygen optimal)	6	36.38	31.20	0.44	4.12	0.04	9.78	0.18	0.00	2.99	0.02
Marschall 2006 (31 oxygen optimal)	6	35.79	30.18	0.49	7.68	0.00	8.29	0.25	0.00	2.94	0.03
Marschall 2006 (31 oxygen optimal)	6	35.92	29.89	0.63	8.48	0.02	7.81	0.28	0.00	3.00	0.02
Marschall 2006 (31 oxygen optimal)	6	35.57	29.62	0.72	8.41	0.00	7.75	0.21	0.00	2.94	0.06
Marschall 2008 (15 YZT optimal)	5	35.10	31.35	1.00	6.99	0.03	7.43	1.33	0.00	1.98	0.32
Marschall 2008 (15 YZT optimal)	5	36.28	31.72	0.05	4.82	0.04	9.11	0.13	0.00	2.69	0.26
Marschall 2008 (15 YZT optimal)	5	35.94	30.04	0.06	6.29	0.02	9.00	0.22	0.00	2.80	0.79
Marschall 2008 (15 YZT optimal)	5	35.74	29.51	0.23	7.78	0.00	7.86	0.53	0.00	2.84	0.71
Marschall 2008 (15 YZT optimal)	5	35.57	29.42	0.24	8.07	0.02	8.00	0.52	0.00	2.82	0.81
Marschall 2008 (15 YZT optimal)	5	35.45	29.83	0.27	7.92	0.05	7.90	0.69	0.00	2.94	0.73
Marschall 2008 (15 YZT optimal)	6	35.90	30.55	0.08	6.98	0.20	8.12	0.08	0.00	2.80	0.16

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Marschall 2008 (15 YZT optimal)	6	35.79	30.45	0.12	6.99	0.18	7.98	0.12	0.00	2.74	0.18
Marschall 2008 (15 YZT optimal)	6	35.85	29.31	0.19	7.86	0.00	8.58	0.40	0.00	2.87	0.27
Marschall 2008 (15 YZT optimal)	6	35.68	29.50	0.25	7.89	0.10	7.92	0.23	0.00	2.83	0.25
Marschall 2008 (15 YZT optimal)	6	35.57	29.10	0.19	7.88	0.02	8.51	0.36	0.00	2.65	0.26
Marschall 2008 (15 YZT optimal)	6	35.19	29.03	0.49	10.15	0.05	6.72	0.15	0.00	2.87	0.33
Marschall 2008 (15 YZT optimal)	6	35.28	29.38	0.17	7.09	0.06	8.95	0.44	0.00	2.80	0.36
Marschall 2008 (15 YZT optimal)	6	35.69	28.95	0.20	7.52	0.02	8.60	0.38	0.00	2.80	0.28
Marschall 2008 (15 YZT optimal)	6	35.09	28.44	0.55	11.53	0.00	6.26	0.25	0.00	2.76	0.26
Marschall 2008 (15 YZT optimal)	6	34.47	27.64	1.00	14.37	0.09	4.23	0.14	0.00	2.82	0.21
Mlynarczak 2006 (15 YZT optimal)	8	34.53	35.11	0.51	10.84	0.06	2.26	0.15	0.00	1.96	0.37
Mlynarczak 2006 (15 YZT optimal)	8	35.69	34.38	0.01	10.53	0.01	3.23	0.24	0.00	1.80	0.11
Mlynarczak 2006 (15 YZT optimal)	8	37.03	33.91	0.00	4.38	0.07	7.47	0.27	0.00	2.13	0.15
Mlynarczak 2006 (15 YZT optimal)	8	35.96	33.64	0.00	9.77	0.01	3.96	0.22	0.00	1.87	0.10
Mlynarczak 2006 (15 YZT optimal)	8	37.04	38.75	0.11	0.33	0.01	7.03	0.20	0.00	1.63	0.21
Mlynarczak 2006 (15 YZT optimal)	8	37.11	38.51	0.11	0.24	0.02	7.15	0.18	0.00	1.73	0.29
Mlynarczak 2006 (15 YZT optimal)	8	35.49	31.96	1.40	9.27	0.07	4.98	0.83	0.00	2.00	0.59
Mlynarczak 2006 (15 YZT optimal)	8	35.23	32.13	1.29	9.08	0.07	4.80	0.56	0.00	2.09	0.60
Mlynarczak 2006 (15 YZT optimal)	8	35.78	32.50	0.37	8.17	0.05	5.66	0.40	0.00	2.25	0.75
Mlynarczak 2006 (15 YZT optimal)	8	36.44	33.20	0.27	7.38	0.04	5.87	0.25	0.00	2.01	0.53
Mlynarczak 2006 (15 YZT optimal)	8	34.99	31.77	1.47	9.20	0.04	5.21	0.61	0.00	2.27	0.40
Mlynarczak 2006 (15 YZT optimal)	8	36.08	33.44	0.01	7.97	0.03	5.54	0.10	0.00	2.20	0.17
Mlynarczak 2006 (15 YZT optimal)	8	36.79	38.51	0.18	0.41	0.01	7.24	0.25	0.00	1.90	0.18
Mlynarczak 2006 (15 YZT optimal)	8	37.03	39.03	0.07	0.24	0.01	7.08	0.15	0.00	1.79	0.10

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Mlynarczak 2006 (15 YZT optimal)	8	36.40	37.76	0.24	4.62	0.01	4.62	0.18	0.00	1.47	0.12
Mlynarczak 2006 (15 YZT optimal)	8	36.47	35.44	0.44	6.49	0.01	4.85	0.29	0.00	1.70	0.25
Mlynarczak 2006 (15 YZT optimal)	8	36.20	35.14	0.40	5.35	0.02	5.73	0.42	0.00	1.93	0.33
Mlynarczak 2006 (15 YZT optimal)	8	35.98	33.86	0.39	6.66	0.03	5.64	0.55	0.00	1.92	0.35
Mlynarczak 2006 (15 YZT optimal)	8	36.25	30.82	1.31	5.90	0.01	7.53	0.93	0.00	2.08	0.20
Mlynarczak 2006 (15 YZT optimal)	8	36.58	33.41	0.00	4.70	0.01	7.38	0.49	0.00	2.17	0.24
Mlynarczak 2006 (15 YZT optimal)	8	36.22	34.77	0.35	6.07	0.01	5.85	0.51	0.00	1.92	0.33
Mlynarczak 2006 (15 YZT optimal)	8	36.37	32.19	0.16	7.66	0.08	6.40	0.75	0.00	2.09	0.38
Mlynarczak 2006 (15 YZT optimal)	8	36.83	33.58	0.01	4.86	0.02	7.25	0.40	0.00	2.20	0.09
Mlynarczak 2006 (15 YZT optimal)	8	36.23	33.00	1.02	6.50	0.01	6.26	0.62	0.00	1.90	0.51
Mlynarczak 2006 (15 YZT optimal)	8	35.89	34.94	0.28	5.21	0.01	5.99	0.54	0.00	1.94	0.40
Mlynarczak 2006 (15 YZT optimal)	8	35.96	35.51	0.22	5.57	0.01	5.66	0.57	0.00	1.81	0.41
Mlynarczak 2006 (15 YZT optimal)	8	36.27	34.16	0.17	7.83	0.03	4.80	0.34	0.00	1.83	0.27
Mlynarczak 2006 (15 YZT optimal)	8	36.34	34.17	0.30	4.17	0.01	7.22	0.50	0.00	2.11	0.53
Mlynarczak 2006 (15 YZT optimal)	8	36.06	32.86	0.74	7.42	0.04	5.60	0.52	0.00	1.86	0.30
Mlynarczak 2006 (15 YZT optimal)	8	36.35	35.86	0.19	4.09	0.00	6.39	0.51	0.00	1.76	0.34
Mlynarczak 2006 (15 YZT optimal)	8	36.17	34.74	0.30	4.31	0.00	6.70	0.61	0.00	1.91	0.37
Mlynarczak 2006 (15 YZT optimal)	8	36.38	30.98	1.98	4.97	0.01	8.02	0.99	0.00	2.03	0.44
Mlynarczak 2006 (15 YZT optimal)	8	36.45	36.25	0.16	2.77	0.01	7.07	0.57	0.00	1.97	0.35
Mlynarczak 2006 (15 YZT optimal)	8	36.50	35.35	0.28	2.98	0.01	7.33	0.47	0.00	2.10	0.56
Mlynarczak 2006 (15 YZT optimal)	8	36.40	37.55	0.11	1.62	0.01	7.09	0.51	0.00	2.02	0.29
Mlynarczak 2006 (15 YZT optimal)	8	36.44	31.67	1.61	4.96	0.01	7.71	0.90	0.00	2.01	0.42
Mlynarczak 2006 (15 YZT optimal)	8	36.18	33.86	0.24	6.70	0.01	6.03	0.60	0.00	2.11	0.23

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Mlynarczak 2006 (15 YZT optimal)	8	36.83	33.59	0.82	1.45	0.00	9.34	0.65	0.00	2.35	0.20
Mlynarczak 2006 (15 YZT optimal)	8	35.81	31.25	1.13	6.64	0.02	7.26	0.94	0.00	2.15	0.27
Mlynarczak 2006 (15 YZT optimal)	8	36.07	32.90	0.72	7.68	0.02	5.22	0.39	0.00	1.83	0.42
Mlynarczak 2006 (15 YZT optimal)	8	36.55	34.46	0.37	4.42	0.01	6.79	0.56	0.00	2.01	0.22
Mlynarczak 2006 (15 YZT optimal)	8	36.71	32.42	0.68	6.02	0.04	6.88	0.45	0.00	2.11	0.26
Mlynarczak 2006 (15 YZT optimal)	8	35.86	32.31	0.79	7.92	0.03	6.00	0.80	0.00	1.99	0.45
Mlynarczak 2006 (15 YZT optimal)	8	36.76	33.40	0.51	5.25	0.01	6.97	0.36	0.00	2.13	0.16
Mlynarczak 2006 (15 YZT optimal)	8	36.72	32.61	0.68	5.81	0.02	7.03	0.51	0.00	2.03	0.31
Mlynarczak 2006 (15 YZT optimal)	8	36.38	34.01	0.03	5.76	0.03	6.24	0.31	0.00	2.16	0.03
Mlynarczak 2006 (15 YZT optimal)	8	36.62	34.19	0.11	6.55	0.05	5.82	0.36	0.00	1.97	0.06
Mlynarczak 2006 (15 YZT optimal)	8	36.48	33.53	0.12	7.57	0.03	5.30	0.26	0.00	1.74	0.19
Mlynarczak 2006 (15 YZT optimal)	8	36.54	33.52	0.58	4.30	0.03	7.55	0.54	0.00	2.12	0.14
Mlynarczak 2006 (15 YZT optimal)	8	35.72	30.38	1.92	3.33	0.02	9.45	1.16	0.00	2.31	0.18
Mlynarczak 2006 (15 YZT optimal)	8	35.96	29.85	2.93	2.21	0.01	10.04	1.25	0.00	2.21	0.18
Mlynarczak 2006 (15 YZT optimal)	8	36.07	31.66	0.73	5.38	0.01	7.54	0.93	0.00	2.24	0.35
Mlynarczak 2006 (15 YZT optimal)	8	35.84	32.76	0.11	7.04	0.01	5.98	0.44	0.00	2.20	0.14
Mlynarczak 2006 (15 YZT optimal)	8	35.69	27.86	2.90	2.98	0.01	10.44	1.93	0.00	1.89	0.33
Mlynarczak 2006 (15 YZT optimal)	8	36.90	36.30	0.16	4.18	0.02	5.38	0.08	0.00	1.46	0.07
Mlynarczak 2006 (15 YZT optimal)	8	36.72	35.30	0.19	4.35	0.02	5.88	0.06	0.00	1.66	0.00
Mlynarczak 2006 (15 YZT optimal)	8	35.55	32.10	0.33	13.65	0.07	1.75	0.17	0.44	1.66	0.14
Mlynarczak 2006 (15 YZT optimal)	8	35.69	31.27	0.68	14.52	0.08	2.13	0.21	0.00	1.98	0.23
Mlynarczak 2006 (15 YZT optimal)	8	35.92	31.90	0.18	13.07	0.00	2.87	0.13	0.00	1.96	0.03
Mlynarczak 2006 (15 YZT optimal)	8	35.20	32.57	0.15	14.16	0.02	1.97	0.11	0.26	1.82	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Mlynarczak 2006 (15 YZT optimal)	8	34.89	29.81	0.15	13.92	0.02	3.17	0.32	0.00	2.22	0.37
Mlynarczak 2006 (15 YZT optimal)	8	35.68	32.20	0.29	13.92	0.04	1.87	0.15	0.40	1.72	0.10
Mlynarczak 2006 (15 YZT optimal)	8	35.79	32.09	0.25	14.30	0.05	1.69	0.19	0.36	1.75	0.06
Mlynarczak 2006 (15 YZT optimal)	8	35.03	30.60	0.73	14.96	0.03	2.13	0.14	0.00	2.15	0.17
Mlynarczak 2006 (15 YZT optimal)	8	35.60	32.86	0.02	13.05	0.01	2.26	0.03	0.00	1.59	0.04
Mlynarczak 2006 (15 YZT optimal)	8	35.96	33.61	0.02	12.11	0.00	2.60	0.04	0.00	1.43	0.04
Mlynarczak 2006 (15 YZT optimal)	8	37.05	34.61	0.31	3.05	0.00	7.57	0.33	0.00	2.02	0.20
Mlynarczak 2006 (15 YZT optimal)	8	37.55	35.81	0.30	2.44	0.00	7.20	0.12	0.00	1.65	0.10
Mlynarczak 2006 (15 YZT optimal)	8	37.18	33.23	0.59	3.45	0.01	8.42	0.65	0.00	1.89	0.36
Mlynarczak 2006 (15 YZT optimal)	8	36.14	31.58	1.11	5.66	0.01	7.75	1.27	0.00	1.90	0.66
Mlynarczak 2006 (15 YZT optimal)	8	36.59	31.11	0.99	4.38	0.01	9.23	1.15	0.00	2.09	0.84
Mlynarczak 2006 (15 YZT optimal)	8	36.29	31.63	0.97	4.48	0.01	8.61	1.23	0.00	1.99	0.72
Mlynarczak 2006 (15 YZT optimal)	8	36.28	29.66	1.35	4.43	0.02	9.95	1.55	0.00	1.98	1.04
Mlynarczak 2006 (15 YZT optimal)	8	36.56	31.24	0.74	4.09	0.01	9.01	1.20	0.00	2.06	0.70
Mlynarczak 2006 (15 YZT optimal)	8	36.56	31.17	0.87	4.32	0.01	8.80	1.34	0.00	1.82	0.61
Mlynarczak 2006 (15 YZT optimal)	8	36.37	32.74	0.22	9.90	0.04	4.30	0.29	0.00	1.84	0.37
Mlynarczak 2006 (15 YZT optimal)	8	36.13	33.64	0.32	10.56	0.07	3.37	0.24	0.00	1.40	0.28
Mlynarczak 2006 (15 YZT optimal)	8	35.44	32.84	0.31	13.66	0.03	1.93	0.26	0.34	1.73	0.16
Mlynarczak 2006 (15 YZT optimal)	8	35.77	33.29	0.28	12.62	0.05	2.29	0.27	0.00	1.62	0.05
Mlynarczak 2006 (15 YZT optimal)	8	33.73	28.97	0.10	17.72	0.03	2.11	0.49	0.00	2.38	0.06
Mlynarczak 2006 (15 YZT optimal)	8	33.94	29.11	0.45	16.80	0.04	2.23	0.67	0.00	2.32	0.17
Mlynarczak 2006 (15 YZT optimal)	8	34.47	29.64	0.43	16.77	0.03	1.90	0.47	0.05	2.23	0.12
Mlynarczak 2006 (15 YZT optimal)	8	33.98	29.65	0.43	16.48	0.03	2.27	0.59	0.00	2.21	0.07

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Mlynarczak 2006 (15 YZT optimal)	8	34.44	29.72	0.29	16.53	0.03	2.19	0.49	0.00	2.35	0.13
Mlynarczak 2006 (15 YZT optimal)	8	35.14	31.06	0.17	14.59	0.03	2.37	0.26	0.00	2.01	0.08
Mlynarczak 2006 (15 YZT optimal)	8	34.46	29.37	0.40	15.62	0.04	2.44	0.57	0.00	2.13	0.21
Mlynarczak 2006 (15 YZT optimal)	8	35.09	32.20	0.19	13.53	0.03	2.28	0.29	0.00	1.81	0.09
Mlynarczak 2006 (15 YZT optimal)	8	34.53	28.35	0.05	17.44	0.01	2.62	0.62	0.00	2.39	0.19
Modreski 1997	5	36.33	26.94	0.54	0.02	0.00	14.93	4.67	0.00	0.46	1.67
Modreski 1997	5	36.59	27.77	0.57	0.05	0.01	14.01	3.91	0.00	0.76	1.39
Modreski 1997	5	35.62	25.62	0.06	4.27	0.00	13.36	3.48	0.00	1.06	1.23
Modreski 1997	5	37.01	29.12	0.38	0.53	0.01	12.92	3.31	0.00	0.98	0.84
Modreski 1997	5	36.18	28.35	0.43	3.77	0.00	11.84	2.83	0.00	1.24	0.50
Modreski 1997	5	36.83	29.59	0.45	0.05	0.01	12.80	2.69	0.00	1.07	1.17
Modreski 1997	5	36.97	33.00	0.17	0.04	0.00	11.14	1.49	0.00	1.23	0.36
Modreski 1997	5	36.52	28.91	0.08	6.88	0.00	9.53	0.63	0.00	2.37	0.13
Modreski 1997	5	37.11	32.07	0.08	3.59	0.00	9.21	0.21	0.00	2.31	0.20
Modreski 1997	5	37.88	33.61	0.06	0.02	0.00	10.17	0.50	0.00	1.16	0.02
Modreski 1997	5	38.14	35.39	0.00	0.02	0.02	9.38	0.01	0.00	0.71	0.21
Morgan 1999 (31 oxygen optimal)	2	35.86	34.11	0.18	12.62	0.20	2.62	0.22	0.16	1.93	0.17
Morgan 1999 (31 oxygen optimal)	2	35.61	34.64	0.24	13.57	0.18	1.62	0.21	0.17	1.72	0.13
Morgan 1999 (31 oxygen optimal)	2	35.40	34.78	0.21	14.45	0.25	1.09	0.16	0.14	1.74	0.13
Morgan 1999 (31 oxygen optimal)	2	35.28	35.29	0.19	14.88	0.43	0.32	0.07	0.15	1.60	0.16
Morgan 1999 (31 oxygen optimal)	2	35.33	36.39	0.14	12.72	1.13	0.02	0.02	0.30	1.46	0.22
Morgan 1999 (31 oxygen optimal)	2	36.87	37.92	0.10	3.19	5.02	0.01	0.13	1.30	2.67	1.30
Morgan 1999 (31 oxygen optimal)	2	37.55	39.50	0.07	0.02	6.68	0.01	0.05	1.39	2.38	1.11
Morgan 1999 (31 oxygen optimal)	2	37.09	38.57	0.24	0.02	6.12	0.01	0.18	1.58	2.76	1.49
Morgan 1999 (31 oxygen optimal)	2	35.78	38.19	0.08	7.22	3.77	0.01	0.01	0.62	1.55	0.50

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Morgan 1999 (31 oxygen optimal)	2	38.24	38.41	0.09	0.61	5.85	0.01	0.07	1.63	2.90	1.68
Morgan 1999 (31 oxygen optimal)	2	35.19	34.44	0.24	13.93	0.22	1.54	0.19	0.13	1.79	0.19
Morgan 1999 (31 oxygen optimal)	2	35.22	34.47	0.25	13.69	0.18	1.74	0.19	0.11	1.74	0.13
Neiva (1974)	1	35.61	33.16	0.68	11.36	0.13	3.26	0.12	0.00	1.88	0.07
Neiva (1974)	1	34.90	36.04	0.73	10.47	0.08	4.39	0.24	0.00	2.11	0.12
Neiva (1974)	1	35.00	33.67	0.31	13.09	0.21	2.67	0.04	0.00	1.96	0.16
Neiva (1974)	1	35.07	33.30	0.58	12.90	0.21	2.07	0.23	0.00	1.93	0.11
Neiva (1974)	1	35.17	34.47	0.13	14.69	0.40	0.21	0.04	0.00	1.92	0.18
Neiva (1974)	1	35.10	33.00	0.66	13.10	0.13	2.94	0.03	0.00	1.43	0.28
Neiva (1974)	1	35.92	33.67	0.41	12.95	0.25	2.15	0.19	0.00	1.97	0.48
Neiva (1974)	1	34.27	32.43	0.62	13.23	0.11	3.44	0.09	0.00	1.84	0.13
Neiva (1974)	1	35.56	33.88	0.38	13.80	0.23	1.47	0.08	0.17	2.00	0.27
Neiva (1974)	1	35.53	33.98	0.39	14.46	0.21	1.61	0.08	0.04	1.93	0.13
Neiva (1974)	1	35.13	33.45	0.47	13.07	0.15	3.12	0.03	0.00	1.98	0.00
Neiva (1974)	1	34.55	33.08	0.46	14.03	0.20	2.72	0.05	0.00	1.76	0.00
Novak 2010	1	36.36	27.88	1.95	6.03	0.00	9.47	2.49	0.00	1.56	0.00
Novak 2010	1	35.92	29.23	2.31	10.01	0.14	5.66	1.29	0.00	2.13	0.00
Novak 2010	1	35.84	27.84	2.22	6.36	0.08	9.00	2.18	0.00	1.75	0.09
Novak 2010	1	35.68	26.61	2.26	8.10	0.11	8.56	2.43	0.00	1.64	0.10
Novak 2010	1	34.63	25.05	2.74	15.02	0.66	4.40	0.87	0.00	2.36	0.70
Novak 2010	1	34.65	24.86	2.96	13.80	0.33	5.68	2.14	0.00	1.68	0.33
Novak 2010	1	34.65	24.86	2.96	13.80	0.33	5.68	2.14	0.00	1.68	0.33
Novak 2010	1	35.67	28.68	1.22	9.25	0.17	6.80	1.49	0.00	2.10	0.07
Novak 2010	1	35.18	31.77	0.84	12.59	2.92	0.69	0.23	0.16	2.44	0.73
Novak 2010	1	35.49	25.82	3.48	10.16	0.34	7.25	2.06	0.00	1.87	0.00
Novak 2010	1	35.69	26.24	2.71	8.78	0.15	7.81	1.97	0.00	1.94	0.25
Povondra 1996	1	34.89	30.45	1.21	14.40	0.10	2.41	0.15	0.01	2.10	0.41

Source	Numeric provenance class for R	SiO ₂	Al ₂ O ₃	TiO ₂	Total as FeO	MnO	MgO	CaO	best Li ₂ O - measured or calculated	Na ₂ O	F
Povondra 1996	1	34.86	32.44	1.12	14.67	0.11	1.81	0.23	0.00	1.76	0.41
Povondra 1996	1	34.95	30.81	0.92	16.05	0.16	1.25	0.12	0.02	1.96	0.44
Povondra 1996	1	34.87	30.84	0.91	15.77	0.12	1.66	0.22	0.02	2.06	0.00
Povondra 1998	1	34.88	32.31	0.67	13.74	0.21	1.60	0.41	0.06	2.24	0.61
Povondra 1998	1	34.72	30.77	1.25	15.25	0.25	0.97	0.74	0.05	1.96	0.71
Povondra 1998	1	35.12	30.89	1.10	13.08	0.14	3.39	0.52	0.05	2.21	0.39
Povondra 1998	1	35.11	30.34	0.99	11.75	0.11	4.14	0.80	0.04	2.70	0.38
Povondra 1998	1	34.99	35.67	0.00	13.99	0.24	0.17	0.08	0.00	1.46	0.00
Sengupta 2011 (15 YZT)	8	36.45	36.25	0.52	5.28	0.01	5.50	0.66	0.00	1.55	0.02
Sengupta 2011 (15 YZT)	8	36.12	35.93	0.42	5.05	0.07	5.84	0.67	0.00	1.72	0.02
Sengupta 2011 (15 YZT)	8	36.58	35.60	0.10	5.36	0.01	5.88	0.46	0.00	1.68	0.04
Sengupta 2011 (15 YZT)	8	36.11	36.87	0.33	4.34	0.01	6.20	0.57	0.00	1.49	0.07
Sengupta 2011 (15 YZT)	8	37.12	41.89	0.05	5.26	0.00	1.35	0.01	0.95	0.26	0.03
Sengupta 2011 (15 YZT)	8	36.75	41.29	0.02	6.04	0.02	1.42	0.05	0.84	0.26	0.01
Sengupta 2011 (15 YZT)	8	37.35	41.23	0.00	6.45	0.01	1.60	0.03	0.85	0.31	0.01
Sengupta 2011 (15 YZT)	8	37.41	41.22	0.02	5.34	0.01	1.94	0.05	1.06	0.40	0.00
Sengupta 2011 (15 YZT)	8	36.40	39.41	0.16	7.50	0.00	1.74	0.38	0.77	0.72	0.02
Sengupta 2011 (15 YZT)	8	36.26	39.96	0.00	7.96	0.00	1.46	0.02	0.60	0.47	0.00
Sengupta 2011 (15 YZT)	8	34.00	43.16	0.43	6.11	0.02	1.46	0.11	0.26	0.59	0.03
Sengupta 2011 (15 YZT)	8	32.59	43.75	0.94	6.07	0.10	1.34	0.19	0.01	0.43	0.02
Sengupta 2011 (15 YZT)	8	35.91	36.11	0.69	9.99	0.06	1.92	0.33	0.65	0.88	0.01
Sengupta 2011 (15 YZT)	8	33.57	36.66	0.16	11.47	0.02	1.85	0.64	0.04	0.56	0.04
Sengupta 2011 (15 YZT)	8	34.44	37.72	0.16	11.61	0.00	1.85	0.72	0.00	0.74	0.03
Sengupta 2011 (15 YZT)	8	34.36	38.80	0.09	11.92	0.00	0.49	0.67	0.00	0.74	0.01
Sengupta 2011 (15 YZT)	8	33.84	38.07	0.13	11.68	0.00	0.76	0.82	0.00	0.61	0.00
Sengupta 2011 (15 YZT)	8	34.30	38.19	0.47	11.47	0.00	0.56	0.70	0.00	0.71	0.02
Sengupta 2011 (15 YZT)	8	35.32	36.64	0.10	12.29	0.07	0.74	0.19	0.10	0.83	0.01
Sengupta 2011 (15 YZT)	8	35.22	36.86	0.12	11.62	0.00	0.78	0.27	0.19	0.80	0.02

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Soares 2008 (31 oxygen optimal)	2	37.89	38.89	0.00	2.11	1.81	0.04	0.11	1.78	2.09	0.80
Soares 2008 (31 oxygen optimal)	2	37.85	38.80	0.01	1.77	1.85	0.03	0.12	1.88	2.22	0.94
Soares 2008 (31 oxygen optimal)	2	37.76	38.09	0.03	1.58	2.65	0.00	0.51	1.93	2.24	1.32
Soares 2008 (31 oxygen optimal)	2	38.39	38.66	0.04	1.19	1.19	0.01	0.78	2.28	2.01	1.23
Soares 2008 (31 oxygen optimal)	2	37.77	41.08	0.02	0.71	0.71	0.00	0.30	1.84	1.80	0.81
Soares 2008 (31 oxygen optimal)	2	38.09	41.19	0.05	0.30	0.30	0.01	0.51	1.96	1.82	0.87
Soares 2008 (31 oxygen optimal)	2	37.99	41.83	0.02	0.20	0.20	0.00	0.09	1.91	1.75	0.65
Soares 2008 (31 oxygen optimal)	2	36.77	40.04	0.04	1.96	1.96	0.00	0.31	1.54	2.12	1.23
Soares 2008 (31 oxygen optimal)	2	38.06	39.72	0.03	1.71	1.91	0.08	0.28	1.77	2.14	1.07
Soares 2008 (31 oxygen optimal)	2	38.05	41.84	0.01	0.13	1.89	0.00	0.08	1.80	1.91	0.65
Soares 2008 (31 oxygen optimal)	2	37.42	38.44	0.08	3.45	1.63	0.01	0.23	1.62	2.22	1.08
Soares 2008 (31 oxygen optimal)	2	37.00	38.00	0.00	3.99	1.24	0.04	0.09	1.31	2.15	0.70
Soares 2008 (31 oxygen optimal)	2	37.48	40.03	0.00	1.24	2.42	0.01	0.24	1.68	2.06	1.04
Soares 2008 (31 oxygen optimal)	2	37.19	39.74	0.00	1.54	2.52	0.01	0.25	1.65	2.22	1.28
Soares 2008 (31 oxygen optimal)	2	37.31	39.65	0.05	1.39	2.40	0.01	0.27	1.68	2.10	1.14
Soares 2008 (31 oxygen optimal)	2	37.44	41.74	0.01	0.02	0.23	0.00	0.06	1.89	1.71	0.55
Soares 2008 (31 oxygen optimal)	2	36.73	40.32	0.01	0.05	0.59	0.02	0.39	1.86	1.83	0.84
Sun (2007) thesis data	7	36.41	30.34	0.68	6.56	0.01	8.62	0.68	0.00	2.59	0.05
Sun (2007) thesis data	7	37.66	32.45	0.40	1.39	0.01	10.81	0.63	0.00	2.21	0.05
Sun (2007) thesis data	7	36.12	33.08	0.46	3.90	0.01	9.26	0.67	0.00	2.56	0.05
Sun (2007) thesis data	7	35.81	31.08	0.56	7.15	0.02	8.01	0.67	0.00	2.17	0.05
Sun (2007) thesis data	7	35.72	30.60	0.52	7.53	0.01	7.82	0.56	0.00	2.34	0.05
Sun (2007) thesis data	7	36.37	31.72	0.47	6.16	0.01	8.38	0.55	0.00	2.25	0.05
Sun (2007) thesis data	7	36.07	32.20	0.48	7.08	0.03	8.18	0.84	0.00	2.14	0.05

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Sun (2007) thesis data	7	35.53	25.89	0.95	15.01	0.04	6.50	0.12	0.00	2.73	0.05
Sun (2007) thesis data	7	35.20	24.75	1.15	15.71	0.01	6.95	0.04	0.00	2.65	0.05
Sun (2007) thesis data	7	35.37	24.62	0.31	15.88	0.01	7.87	0.01	0.00	2.81	0.05
Sun (2007) thesis data	7	35.43	25.83	1.36	13.45	0.01	7.09	0.00	0.00	3.00	0.05
Tindle (2002)	2	33.42	31.32	0.60	12.97	0.30	3.18	0.20	0.00	2.46	0.49
Tindle (2002)	2	33.73	31.55	0.60	12.96	0.30	2.91	0.19	0.02	2.38	0.44
Tindle (2002)	2	33.62	31.91	0.58	13.13	0.32	2.91	0.17	0.00	2.43	0.38
Tindle (2002)	2	33.54	31.38	0.78	12.81	0.29	3.01	0.18	0.02	2.41	0.49
Tindle (2002)	2	34.45	35.09	0.31	8.97	0.97	1.05	0.15	0.74	2.48	0.96
Tindle (2002)	2	35.25	35.56	0.27	8.95	0.94	0.97	0.14	0.79	2.40	0.99
Tindle (2002)	2	34.93	35.69	0.23	8.79	1.02	1.08	0.16	0.76	2.48	1.06
Tindle (2002)	2	34.54	35.63	0.27	9.87	0.97	1.07	0.15	0.60	2.46	0.84
Tindle (2002)	6	34.85	29.45	0.50	10.22	0.05	6.95	1.65	0.00	2.03	0.54
Tindle (2002)	6	34.86	30.37	0.32	9.08	0.04	7.17	1.38	0.00	2.08	0.72
Tindle (2002)	6	35.02	29.07	0.33	9.22	0.05	7.27	1.86	0.09	1.88	0.64
Tindle (2002)	6	34.19	30.08	0.39	10.23	0.04	6.56	1.32	0.00	2.08	0.27
Tindle (2002)	6	34.24	29.58	0.39	10.33	0.05	6.73	1.39	0.00	2.12	0.25
Tindle (2002)	6	34.82	28.51	0.54	10.44	0.05	6.96	1.69	0.00	1.92	0.51
Tindle (2002)	6	34.93	28.90	0.59	10.63	0.05	6.65	1.44	0.02	2.11	0.52
Tindle (2002)	6	35.16	29.46	0.54	10.16	0.03	7.00	1.45	0.02	2.17	0.56
Tindle (2002)	6	35.15	29.02	0.96	10.02	0.05	6.98	1.60	0.07	2.01	0.60
Tindle (2002)	6	34.84	29.22	0.83	9.75	0.04	7.28	1.50	0.00	2.00	0.69
Tindle (2002)	6	34.80	29.13	0.83	9.80	0.03	7.26	1.53	0.00	2.01	0.57
Tindle (2002)	6	35.19	29.61	0.53	9.06	0.03	7.35	1.29	0.01	2.06	0.77
Tindle (2002)	6	34.37	30.13	0.59	9.23	0.02	7.17	1.26	0.00	2.10	0.62
Tindle (2002)	6	36.40	31.03	0.75	4.38	0.01	9.14	1.63	0.25	1.66	0.25
Tindle (2002)	6	36.67	31.14	0.58	4.43	0.00	9.21	1.62	0.26	1.79	0.14
Tindle (2002)	6	36.22	31.14	0.79	4.33	0.03	9.18	1.68	0.25	1.70	0.15

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Tindle (2002)	6	36.50	30.86	0.93	4.58	0.02	9.09	1.72	0.27	1.59	0.27
Tindle (2002)	6	36.46	30.28	0.92	4.58	0.01	9.24	1.89	0.28	1.56	0.21
Tindle (2002)	6	36.79	30.58	0.88	4.62	0.02	9.35	1.97	0.28	1.51	0.18
Tindle (2002)	6	36.77	30.59	0.98	4.67	0.03	9.40	1.81	0.25	1.61	0.20
Tindle (2002)	6	36.55	31.13	0.84	4.47	0.01	9.19	1.51	0.23	1.74	0.14
Tindle (2002)	6	36.37	30.54	1.04	4.53	0.02	9.25	1.93	0.28	1.55	0.18
Tindle (2002)	6	36.44	30.58	0.91	4.50	0.01	9.16	1.82	0.28	1.55	0.14
Tindle (2003)	2	35.54	35.26	0.12	7.52	1.19	0.21	0.14	0.89	2.34	0.76
Tindle (2003)	2	34.11	36.19	0.55	8.23	1.32	0.10	1.13	0.99	2.08	1.06
Tindle (2003)	2	33.78	36.01	0.50	8.78	1.42	0.15	0.88	0.77	2.07	0.90
Tindle (2003)	2	33.80	37.03	0.22	6.45	2.55	0.16	0.62	0.80	2.26	1.03
Tindle (2003)	2	33.89	37.48	0.11	5.52	2.67	0.05	0.79	0.91	2.23	0.99
Tindle (2003)	2	33.58	36.60	0.55	8.11	1.44	0.08	1.18	0.92	2.04	0.98
Tindle (2003)	2	33.67	36.39	0.60	8.22	1.36	0.09	1.26	0.95	1.96	0.96
Tindle (2003)	2	33.50	36.13	0.58	8.28	1.26	0.08	1.25	0.95	2.01	0.93
Tindle (2003)	2	33.96	36.75	0.28	6.14	1.93	0.18	1.16	1.11	2.09	1.10
Tindle (2003)	2	33.56	34.93	0.43	10.33	1.18	0.49	0.35	0.35	2.04	0.63
Tindle (2003)	2	34.09	37.24	0.09	4.95	2.74	0.03	0.70	0.95	2.31	1.00
Tindle (2003)	2	34.32	37.03	0.23	5.78	2.26	0.16	0.89	1.00	2.15	0.88
Tindle (2003)	2	34.22	35.97	0.52	7.91	0.93	0.42	0.68	0.88	1.97	0.58
Tindle (2003)	2	34.40	36.50	0.35	6.45	1.18	0.40	0.77	1.08	2.06	0.80
Tindle (2003)	2	35.22	35.42	0.18	9.36	1.02	0.34	0.12	0.59	1.85	0.49
Tindle (2003)	2	34.87	35.43	0.18	9.54	1.04	0.37	0.12	0.50	1.70	0.45
Tindle (2003)	2	35.48	35.44	0.17	9.69	1.07	0.36	0.11	0.50	1.64	0.34
Tindle (2003)	2	35.29	35.49	0.14	9.77	1.13	0.36	0.09	0.47	1.65	0.25
Tindle (2003)	2	35.34	35.52	0.14	9.71	1.06	0.37	0.12	0.50	1.72	0.27
Tindle (2003)	2	35.17	35.64	0.15	9.65	1.07	0.34	0.10	0.49	1.66	0.35
Tindle (2003)	2	35.42	35.46	0.13	9.52	1.06	0.38	0.12	0.53	1.68	0.34

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Tindle (2003)	2	34.69	35.88	0.48	8.78	0.95	0.49	0.42	0.72	2.03	0.60
Tindle (2003)	2	34.39	36.35	0.44	8.20	0.96	0.45	0.63	0.78	2.02	0.55
Tindle (2003)	2	34.61	37.60	0.34	5.66	1.49	0.41	1.13	1.16	1.97	0.94
Tindle (2003)	2	34.84	37.11	0.34	6.24	1.31	0.29	1.24	1.22	1.97	1.00
Tindle (2003)	2	34.60	36.88	0.39	6.20	1.27	0.25	1.32	1.25	1.94	1.03
Tindle (2003)	2	35.65	35.66	0.38	8.55	0.98	0.42	0.33	0.81	2.06	0.57
Tindle (2003)	2	35.68	35.12	0.11	10.36	0.93	0.36	0.07	0.43	1.58	0.37
Tindle (2003)	2	35.79	37.09	0.32	5.44	1.51	0.42	0.89	1.27	2.10	0.88
Tindle (2003)	2	34.74	37.61	0.29	5.20	1.59	0.37	1.22	1.26	2.02	0.90
Tindle (2003)	2	35.12	37.29	0.28	5.52	1.46	0.32	1.15	1.27	2.00	1.01
Tindle (2003)	2	35.29	35.30	0.43	8.47	0.93	0.45	0.42	0.83	2.07	0.60
Tindle (2003)	2	35.42	35.18	0.42	8.35	0.98	0.41	0.42	0.87	2.12	0.61
Tindle (2003)	2	35.09	35.07	0.40	8.43	0.96	0.44	0.42	0.82	2.03	0.68
Tindle (2003)	2	34.13	37.19	0.34	6.13	1.37	0.36	0.94	1.06	2.08	0.87
Tindle (2003)	2	34.90	37.27	0.25	5.19	1.61	0.37	1.05	1.25	2.06	1.03
Tindle (2003)	2	34.74	37.43	0.28	5.03	1.64	0.38	1.17	1.27	2.02	0.99
Tindle (2003)	2	34.48	37.54	0.29	5.16	1.52	0.37	1.15	1.25	2.00	0.95
Tindle (2003)	2	34.33	37.17	0.31	5.36	1.51	0.37	1.20	1.24	2.03	0.92
Tindle (2003)	2	34.31	36.78	0.36	5.89	1.36	0.32	1.13	1.21	2.03	0.99
Tindle (2003)	2	34.42	36.95	0.36	5.95	1.34	0.30	1.17	1.22	2.05	0.93
Tindle (2003)	2	34.06	37.29	0.31	6.06	1.28	0.26	1.22	1.18	2.00	0.96
Tindle (2003)	2	34.73	37.07	0.27	5.87	1.28	0.28	1.24	1.26	1.99	1.02
Tindle (2003)	2	35.75	35.42	0.09	9.67	0.86	0.19	0.13	0.59	1.72	0.42
Tindle (2003)	2	35.03	34.76	0.28	10.45	0.74	0.37	0.24	0.52	1.86	0.41
Tindle (2003)	2	35.99	34.84	0.05	10.37	0.88	0.22	0.08	0.52	1.62	0.34
Tindle (2003)	2	35.26	34.80	0.33	9.83	0.72	0.37	0.33	0.67	1.94	0.56
Tindle (2003)	2	36.10	34.59	0.28	9.39	0.70	0.32	0.26	0.84	2.17	0.58
Tindle (2003)	2	36.11	34.92	0.16	9.46	0.62	0.39	0.18	0.82	2.14	0.64

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Tindle (2003)	2	34.87	36.72	0.37	6.64	1.42	0.38	0.91	1.11	2.13	0.79
Tindle (2003)	2	35.32	36.91	0.34	5.98	1.51	0.36	1.14	1.26	2.05	1.06
Tindle (2003)	2	35.92	36.81	0.24	5.58	1.52	0.26	1.11	1.39	2.12	1.15
Tindle (2003)	2	35.72	35.86	0.43	7.72	1.08	0.42	0.68	1.01	2.06	0.69
Tindle (2003)	2	35.46	36.18	0.40	7.68	1.07	0.45	0.71	0.98	2.03	0.81
Tindle (2003)	2	34.74	37.76	0.36	5.98	1.51	0.33	1.22	1.21	2.04	0.94
Tindle (2003)	2	34.59	37.64	0.33	5.75	1.60	0.34	1.31	1.24	2.03	1.05
Tindle (2003)	2	34.52	37.79	0.19	4.97	1.87	0.21	1.49	1.35	1.96	1.18
Tindle (2003)	2	34.28	37.76	0.14	4.85	1.91	0.19	1.54	1.34	1.90	1.12
Tindle (2003)	2	34.43	37.65	0.30	5.83	1.55	0.32	1.25	1.21	1.99	0.96
Tindle (2003)	2	34.21	37.72	0.29	5.78	1.54	0.29	1.30	1.22	2.04	0.90
Tindle (2003)	2	34.22	37.72	0.33	5.81	1.57	0.30	1.34	1.22	2.02	1.01
Tindle (2003)	2	34.31	37.68	0.33	5.79	1.58	0.28	1.35	1.23	2.01	0.81
Tindle (2003)	2	34.87	34.72	0.38	10.05	0.76	0.86	0.25	0.47	1.94	0.40
Tindle (2003)	2	35.24	34.56	0.39	9.58	0.87	0.54	0.22	0.62	2.03	0.67
Tindle (2003)	2	35.33	34.51	0.14	10.86	0.92	0.43	0.06	0.30	1.35	0.24
Tindle (2003)	2	35.39	34.89	0.10	10.91	0.92	0.41	0.03	0.29	1.39	0.18
Tindle (2003)	2	35.40	35.05	0.12	10.90	0.93	0.43	0.05	0.29	1.38	0.02
Tindle (2003)	2	35.22	35.04	0.22	10.14	0.83	0.48	0.10	0.46	1.62	0.31
Tindle (2003)	2	35.20	35.11	0.21	10.13	0.86	0.46	0.09	0.43	1.65	0.25
Tindle (2003)	2	35.45	35.12	0.23	10.15	0.86	0.45	0.12	0.43	1.67	0.33
Tindle (2003)	2	35.60	35.12	0.25	10.09	0.86	0.44	0.13	0.45	1.64	0.29
Tindle (2003)	2	35.48	35.12	0.11	10.67	0.92	0.39	0.07	0.48	1.49	0.13
Tindle (2003)	2	35.41	35.16	0.09	10.68	0.97	0.39	0.05	0.35	1.44	0.08
Tindle (2003)	2	35.44	35.14	0.09	10.63	0.95	0.38	0.06	0.31	1.46	0.04
Tindle (2003)	2	35.18	35.86	0.23	7.38	1.14	0.47	0.51	0.34	1.98	0.82
Tindle (2003)	2	34.95	34.72	0.23	10.15	0.86	0.57	0.09	0.88	1.65	0.19
Tindle (2003)	2	35.11	34.68	0.09	10.72	0.84	0.55	0.05	0.42	1.42	0.07

ource	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Tindle (2003)	2	35.12	34.79	0.11	10.77	0.85	0.57	0.05	0.30	1.35	0.19
Tindle (2003)	2	35.00	34.85	0.11	10.47	0.80	0.58	0.06	0.28	1.51	0.37
Tindle (2003)	2	34.20	35.00	0.68	9.75	0.70	0.60	0.52	0.63	1.95	0.46
Tindle (2003)	2	35.42	34.49	0.59	9.66	0.75	0.43	0.54	0.78	1.95	0.59
Tindle (2003)	2	34.79	34.56	0.58	9.61	0.73	0.50	0.66	0.76	1.86	0.48
Tindle (2003)	2	34.75	34.02	0.53	10.40	0.82	0.62	0.27	0.53	1.92	0.44
Tindle (2003)	2	34.60	34.14	0.57	10.16	0.69	0.58	0.36	0.60	1.95	0.56
Tindle (2003)	2	33.75	35.55	0.61	8.86	0.76	0.45	0.70	0.73	1.90	0.65
Tindle (2003)	2	34.85	34.75	0.57	8.54	0.78	0.40	0.61	0.89	1.95	0.64
Tindle (2003)	2	35.23	37.60	0.12	2.71	2.95	0.01	1.32	1.54	2.03	1.32
Tindle (2003)	2	35.03	38.18	0.12	3.23	2.98	0.03	1.13	1.35	2.20	1.30
Tindle (2003)	2	34.68	37.64	0.20	4.54	2.76	0.04	1.07	1.21	2.20	1.24
Tindle (2003)	2	34.91	37.71	0.13	3.77	2.81	0.02	1.42	1.37	1.97	1.19
Tindle (2003)	2	35.65	38.00	0.06	2.13	2.75	0.18	1.93	1.68	1.66	1.21
Tindle (2003)	2	36.55	37.65	0.03	2.25	2.48	0.02	2.05	1.85	1.73	1.49
Tindle (2003)	2	36.59	37.50	0.04	2.05	2.08	0.15	2.11	1.89	1.59	1.29
Tindle (2003)	2	35.50	38.91	0.03	1.36	2.09	0.00	2.31	1.90	1.40	1.43
Tindle (2003)	2	35.27	38.41	0.04	1.56	2.61	0.01	2.07	1.80	1.62	1.41
Tindle (2003)	2	34.92	37.84	0.18	4.40	2.64	0.01	1.27	1.27	2.06	1.17
Tindle (2003)	2	35.21	37.98	0.17	4.25	2.61	0.02	1.41	1.33	1.97	1.18
Tindle (2003)	2	34.73	37.65	0.15	3.70	2.79	0.03	1.53	1.39	1.93	1.26
Tindle (2003)	2	35.26	38.42	0.06	1.92	2.87	0.02	2.03	1.71	1.68	1.28
Tindle (2003)	2	35.19	39.24	0.03	1.03	1.81	0.00	2.65	2.01	1.29	1.37
Tindle (2003)	2	35.19	38.76	0.05	1.55	1.77	0.01	2.65	1.95	1.34	1.46
Tindle (2003)	2	35.75	38.65	0.03	1.11	1.75	0.02	2.57	2.04	1.29	1.43
Tindle (2003)	2	35.35	39.16	0.02	0.96	1.92	0.00	2.56	1.99	1.28	1.27
Tindle (2003)	2	35.03	36.60	0.24	6.49	1.67	0.10	0.51	0.86	2.07	0.65
Tindle (2003)	2	34.87	36.32	0.25	6.87	1.46	0.13	0.52	0.84	2.03	0.64

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Tindle (2003)	2	34.87	36.74	0.30	5.99	1.63	0.11	0.53	0.88	2.10	0.67
Tindle (2003)	2	35.51	34.78	0.28	9.84	0.83	0.61	0.24	0.58	1.94	0.37
Tindle (2003)	2	35.25	35.46	0.34	8.30	0.84	0.40	0.60	0.82	1.96	0.68
Tindle (2003)	2	35.63	34.59	0.05	9.21	0.84	0.52	0.25	0.71	2.05	0.71
Tindle (2003)	2	35.32	34.62	0.36	10.10	0.80	0.71	0.30	0.55	1.95	0.37
Tindle (2003)	2	35.35	34.55	0.23	10.41	0.73	0.82	0.22	0.47	1.89	0.29
Tindle (2003)	2	34.67	35.92	0.47	8.73	0.98	0.39	0.46	0.79	2.06	0.51
Tindle (2003)	2	34.28	35.76	0.49	9.11	0.80	0.40	0.78	0.79	1.92	0.57
Tindle (2003)	2	35.17	35.26	0.15	9.90	0.86	0.39	0.32	0.64	2.02	0.65
Tindle (2003)	2	35.16	35.23	0.21	9.86	0.86	0.38	0.31	0.65	2.02	0.57
Tindle (2003)	2	34.85	34.22	0.33	10.99	0.64	0.49	0.64	0.62	1.96	0.59
Tindle (2003)	2	34.85	35.25	0.28	10.14	0.76	0.54	0.42	0.59	1.94	0.49
Tindle (2003)	2	34.94	35.07	0.15	10.67	0.86	0.48	0.25	0.49	2.00	0.46
Tindle (2003)	2	34.53	34.43	0.33	10.53	0.67	0.50	0.51	0.58	1.91	0.60
Tindle (2003)	2	35.17	34.95	0.17	10.17	0.85	0.36	0.24	0.64	2.01	0.60
Trumbull 2008 (15 YZT optimal)	1	34.88	30.59	0.26	18.00	0.18	0.15	0.14	0.00	2.42	1.37
Trumbull 2008 (15 YZT optimal)	1	35.95	31.60	0.02	17.44	0.09	0.00	0.02	0.00	1.84	0.57
Trumbull 2008 (15 YZT optimal)	1	34.90	30.13	0.46	18.16	0.14	0.25	0.16	0.00	2.44	1.23
Trumbull 2008 (15 YZT optimal)	1	35.72	31.20	0.01	18.45	0.12	0.01	0.01	0.03	2.15	0.88
Trumbull 2008 (15 YZT optimal)	1	34.52	30.68	0.65	17.84	0.09	0.43	0.12	0.04	2.44	1.25
Trumbull 2008 (15 YZT optimal)	1	34.80	31.44	0.34	17.72	0.16	0.10	0.10	0.03	2.34	1.32
Trumbull 2008 (15 YZT optimal)	1	35.03	29.01	0.46	18.99	0.13	0.26	0.02	0.04	2.49	1.10
Trumbull 2008 (15 YZT optimal)	1	34.84	30.22	0.15	18.14	0.08	0.23	0.04	0.00	2.40	0.91
Trumbull 2008 (15 YZT optimal)	1	34.79	30.63	0.49	17.65	0.14	0.32	0.09	0.03	2.34	1.06
Trumbull 2008 (15 YZT optimal)	1	34.86	29.46	0.04	18.93	0.11	0.02	0.04	0.00	2.57	1.30

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2008 (15 YZT optimal)	1	34.63	28.81	0.12	19.84	0.13	0.12	0.02	0.00	2.65	1.17
Trumbull 2008 (15 YZT optimal)	1	34.86	29.88	0.13	18.92	0.13	0.25	0.02	0.00	2.48	0.90
Trumbull 2008 (15 YZT optimal)	1	34.60	30.65	0.70	17.58	0.09	0.54	0.17	0.00	2.46	1.33
Trumbull 2008 (15 YZT optimal)	1	34.55	29.47	0.02	19.15	0.12	0.02	0.03	0.00	2.35	0.73
Trumbull 2008 (15 YZT optimal)	1	35.02	30.26	0.62	18.01	0.13	0.25	0.17	0.00	2.49	1.33
Trumbull 2008 (15 YZT optimal)	1	35.21	31.59	0.68	16.91	0.08	0.50	0.15	0.00	2.19	1.23
Trumbull 2008 (15 YZT optimal)	1	35.26	30.36	0.02	18.36	0.10	0.02	0.02	0.00	2.15	1.05
Trumbull 2008 (15 YZT optimal)	1	35.28	30.55	0.03	19.10	0.11	0.00	0.01	0.00	2.08	0.78
Trumbull 2008 (15 YZT optimal)	1	35.23	29.43	0.01	19.70	0.10	0.00	0.04	0.00	2.30	1.02
Trumbull 2008 (15 YZT optimal)	1	35.52	32.16	0.47	16.24	0.12	0.44	0.08	0.00	2.03	1.23
Trumbull 2008 (15 YZT optimal)	1	35.54	32.11	0.49	16.00	0.10	0.45	0.08	0.00	2.00	1.17
Trumbull 2008 (15 YZT optimal)	1	34.96	31.34	0.65	17.05	0.07	0.47	0.16	0.04	2.20	1.22
Trumbull 2008 (15 YZT optimal)	1	35.24	31.79	0.68	16.32	0.11	0.39	0.08	0.02	2.11	1.16
Trumbull 2008 (15 YZT optimal)	1	35.55	31.08	0.01	18.47	0.10	0.00	0.01	0.00	2.14	0.78
Trumbull 2008 (15 YZT optimal)	1	35.01	30.14	0.02	19.46	0.16	0.03	0.00	0.00	2.46	1.24
Trumbull 2008 (15 YZT optimal)	1	35.42	30.54	0.63	17.96	0.10	0.31	0.06	0.00	2.45	1.40
Trumbull 2008 (15 YZT optimal)	1	35.46	30.38	0.02	19.39	0.11	0.00	0.01	0.00	2.21	0.90
Trumbull 2008 (15 YZT optimal)	1	35.08	29.87	0.75	19.05	0.16	0.36	0.07	0.00	2.53	1.44
Trumbull 2008 (15 YZT optimal)	1	35.06	29.64	0.53	18.96	0.19	0.38	0.06	0.00	2.50	1.39
Trumbull 2008 (15 YZT optimal)	1	35.11	30.15	0.03	19.36	0.14	0.03	0.04	0.00	2.46	1.27
Trumbull 2008 (15 YZT optimal)	1	35.84	31.74	0.01	17.97	0.12	0.02	0.02	0.00	1.93	0.58
Trumbull 2008 (15 YZT optimal)	1	37.43	36.62	0.13	10.01	0.01	0.12	0.10	0.78	2.15	1.11
Trumbull 2008 (15 YZT optimal)	1	34.80	32.06	0.08	16.94	0.06	0.69	0.34	0.00	1.88	0.26

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2008 (15 YZT optimal)	1	35.31	30.75	0.02	18.82	0.08	0.48	0.12	0.00	2.13	0.21
Trumbull 2008 (15 YZT optimal)	1	34.85	29.94	0.08	19.41	0.12	0.40	0.15	0.00	2.11	0.55
Trumbull 2008 (15 YZT optimal)	1	34.93	34.62	0.29	13.80	0.03	1.00	0.21	0.03	1.89	0.15
Trumbull 2008 (15 YZT optimal)	1	35.67	33.73	0.20	15.15	0.08	0.54	0.10	0.03	1.88	0.40
Trumbull 2008 (15 YZT optimal)	1	35.43	33.54	0.17	14.34	0.08	0.79	0.05	0.00	2.11	0.18
Trumbull 2008 (15 YZT optimal)	1	35.47	33.33	0.19	14.56	0.06	1.23	0.13	0.00	2.02	0.20
Trumbull 2008 (15 YZT optimal)	1	35.38	32.69	0.41	14.71	0.07	1.67	0.08	0.00	2.15	0.95
Trumbull 2008 (15 YZT optimal)	1	35.57	32.60	0.41	14.79	0.10	1.71	0.10	0.00	2.14	0.96
Trumbull 2008 (15 YZT optimal)	1	35.64	31.70	0.59	15.19	0.10	1.88	0.09	0.00	2.20	0.87
Trumbull 2008 (15 YZT optimal)	1	36.04	33.74	0.30	14.28	0.08	1.37	0.02	0.00	2.11	0.07
Trumbull 2008 (15 YZT optimal)	1	35.83	31.66	0.46	15.19	0.09	1.96	0.07	0.00	2.74	0.78
Trumbull 2008 (15 YZT optimal)	1	35.43	29.63	0.75	17.52	0.11	1.40	0.07	0.00	2.88	0.77
Trumbull 2008 (15 YZT optimal)	1	36.07	33.50	0.17	14.80	0.05	1.06	0.02	0.00	2.10	0.45
Trumbull 2008 (15 YZT optimal)	1	35.52	32.19	0.49	14.21	0.08	1.98	0.11	0.00	2.44	0.72
Trumbull 2008 (15 YZT optimal)	1	36.14	32.92	0.48	13.86	0.12	1.95	0.10	0.00	2.27	0.43
Trumbull 2008 (15 YZT optimal)	1	35.87	31.84	0.60	14.66	0.11	2.06	0.07	0.00	2.52	0.83
Trumbull 2008 (15 YZT optimal)	1	35.89	31.25	0.34	15.45	0.08	1.84	0.05	0.00	2.81	1.04
Trumbull 2008 (15 YZT optimal)	1	35.35	31.99	0.23	15.77	0.14	1.35	0.05	0.00	2.15	0.95
Trumbull 2008 (15 YZT optimal)	1	34.45	32.13	1.07	14.27	0.12	2.10	0.63	0.00	2.13	1.28
Trumbull 2008 (15 YZT optimal)	1	34.42	31.85	0.99	14.49	0.10	2.33	0.65	0.00	2.10	1.13
Trumbull 2008 (15 YZT optimal)	1	36.04	32.28	0.57	14.20	0.14	2.01	0.08	0.00	2.49	0.41
Trumbull 2008 (15 YZT optimal)	1	36.03	30.98	0.71	15.14	0.14	2.09	0.10	0.00	2.68	1.20
Trumbull 2008 (15 YZT optimal)	1	36.78	33.36	0.33	14.12	0.04	1.29	0.01	0.02	1.70	0.40

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2008 (15 YZT optimal)	1	35.46	27.49	1.91	16.40	0.17	2.83	0.12	0.01	2.67	0.91
Trumbull 2008 (15 YZT optimal)	1	35.85	29.10	1.28	15.46	0.12	2.75	0.08	0.01	2.56	0.96
Trumbull 2008 (15 YZT optimal)	1	35.66	28.21	1.76	16.24	0.15	2.62	0.10	0.00	2.53	0.95
Trumbull 2008 (15 YZT optimal)	1	35.77	30.81	0.77	15.01	0.11	1.97	0.07	0.00	2.33	0.81
Trumbull 2008 (15 YZT optimal)	1	34.41	30.47	1.14	14.40	0.10	2.49	0.90	0.00	2.20	1.44
Trumbull 2008 (15 YZT optimal)	1	34.50	30.62	1.06	14.75	0.09	2.45	0.83	0.00	2.19	1.34
Trumbull 2008 (15 YZT optimal)	1	34.55	30.94	1.07	14.67	0.02	2.25	0.76	0.00	2.28	1.43
Trumbull 2008 (15 YZT optimal)	1	34.66	31.16	0.91	14.70	0.08	2.28	0.80	0.00	2.23	1.43
Trumbull 2008 (15 YZT optimal)	1	34.78	31.13	1.00	14.94	0.07	2.06	0.70	0.00	2.19	1.20
Trumbull 2008 (15 YZT optimal)	1	34.81	31.51	0.84	14.39	0.10	1.90	0.51	0.00	2.14	1.19
Trumbull 2008 (15 YZT optimal)	1	35.81	30.50	0.75	14.80	0.14	2.27	0.08	0.01	2.37	0.97
Trumbull 2008 (15 YZT optimal)	1	36.24	30.58	0.52	13.90	0.07	2.89	0.06	0.00	2.59	1.08
Trumbull 2008 (15 YZT optimal)	1	34.78	31.27	0.96	14.61	0.07	1.99	0.63	0.27	2.20	1.26
Trumbull 2008 (15 YZT optimal)	1	35.66	32.02	0.42	14.48	0.07	1.82	0.10	0.31	2.20	0.64
Trumbull 2008 (15 YZT optimal)	1	35.58	28.45	1.41	16.36	0.12	2.48	0.11	0.00	2.52	0.97
Trumbull 2008 (15 YZT optimal)	1	35.62	27.83	1.73	16.91	0.19	2.71	0.10	0.00	2.52	0.87
Trumbull 2008 (15 YZT optimal)	4	37.83	34.43	0.25	6.03	0.01	6.58	0.54	0.00	1.56	0.00
Trumbull 2008 (15 YZT optimal)	4	37.54	33.81	0.49	5.79	0.04	6.73	0.73	0.00	1.69	0.00
Trumbull 2008 (15 YZT optimal)	4	37.82	34.19	0.28	6.02	0.01	6.57	0.55	0.00	1.58	0.00
Trumbull 2008 (15 YZT optimal)	4	36.87	30.14	1.05	10.07	0.04	5.94	0.57	0.00	2.23	0.00
Trumbull 2008 (15 YZT optimal)	4	35.37	31.90	1.18	10.64	0.30	4.44	0.88	0.00	2.12	0.48
Trumbull 2008 (15 YZT optimal)	4	36.09	31.00	0.91	10.36	0.36	4.95	0.91	0.00	2.09	0.51
Trumbull 2009 (15 YZT optimal)	4	37.13	31.56	0.19	3.15	0.03	9.76	0.99	0.00	2.32	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.05	31.69	0.18	3.10	0.06	9.91	0.95	0.00	2.33	0.00
Trumbull 2009 (15 YZT optimal)	4	36.90	31.86	0.13	3.10	0.02	9.76	0.80	0.00	2.39	0.00
Trumbull 2009 (15 YZT optimal)	4	37.10	31.72	0.15	3.19	0.00	9.58	0.81	0.00	2.46	0.00
Trumbull 2009 (15 YZT optimal)	4	37.77	31.86	0.17	3.16	0.03	9.59	0.70	0.00	2.36	0.00
Trumbull 2009 (15 YZT optimal)	4	36.79	31.64	0.17	3.22	0.02	9.60	0.80	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.48	31.49	0.15	3.11	0.04	9.57	0.82	0.00	2.37	0.00
Trumbull 2009 (15 YZT optimal)	4	37.26	31.51	0.18	3.08	0.02	9.79	0.93	0.00	2.32	0.00
Trumbull 2009 (15 YZT optimal)	4	37.23	31.74	0.21	3.04	0.02	9.77	0.95	0.00	2.29	0.00
Trumbull 2009 (15 YZT optimal)	4	37.57	31.59	0.18	2.97	0.04	9.81	0.99	0.00	2.31	0.00
Trumbull 2009 (15 YZT optimal)	4	37.51	31.32	0.16	2.99	0.00	9.81	0.88	0.00	2.33	0.00
Trumbull 2009 (15 YZT optimal)	4	36.78	31.65	0.18	2.96	0.03	9.83	0.92	0.00	2.33	0.00
Trumbull 2009 (15 YZT optimal)	4	37.36	31.59	0.18	3.07	0.00	9.94	0.90	0.00	2.34	0.00
Trumbull 2009 (15 YZT optimal)	4	37.24	30.95	0.30	3.63	0.02	9.95	1.05	0.00	2.28	0.02
Trumbull 2009 (15 YZT optimal)	4	36.98	31.14	0.13	3.33	0.01	9.46	0.78	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.70	31.89	0.11	3.09	0.02	9.80	0.78	0.00	2.51	0.00
Trumbull 2009 (15 YZT optimal)	4	37.18	31.58	0.15	3.12	0.01	9.67	0.93	0.00	2.33	0.00
Trumbull 2009 (15 YZT optimal)	4	37.30	31.09	0.26	3.35	0.01	9.92	1.16	0.00	2.29	0.00
Trumbull 2009 (15 YZT optimal)	4	37.34	30.67	0.37	3.58	0.04	10.07	1.07	0.00	2.29	0.00
Trumbull 2009 (15 YZT optimal)	4	37.72	31.87	0.11	2.88	0.05	9.70	0.43	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.28	31.41	0.21	3.30	0.03	9.62	0.90	0.00	2.41	0.00
Trumbull 2009 (15 YZT optimal)	4	37.57	31.54	0.17	3.08	0.02	9.49	0.83	0.00	2.35	0.00
Trumbull 2009 (15 YZT optimal)	4	37.47	31.35	0.14	3.09	0.01	9.67	0.81	0.00	2.46	0.00
Trumbull 2009 (15 YZT optimal)	4	37.44	31.62	0.21	2.96	0.00	9.83	0.95	0.00	2.29	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.52	31.16	0.31	2.95	0.00	9.84	0.92	0.00	2.29	0.00
Trumbull 2009 (15 YZT optimal)	4	37.88	31.54	0.28	3.12	0.04	9.82	0.76	0.00	2.45	0.00
Trumbull 2009 (15 YZT optimal)	4	37.56	31.47	0.22	3.28	0.01	9.51	0.85	0.00	2.49	0.00
Trumbull 2009 (15 YZT optimal)	4	37.47	31.25	0.25	3.25	0.02	9.62	0.79	0.00	2.37	0.00
Trumbull 2009 (15 YZT optimal)	4	37.84	32.03	0.15	2.97	0.03	9.58	0.45	0.00	2.40	0.00
Trumbull 2009 (15 YZT optimal)	4	37.82	31.77	0.25	3.16	0.00	9.56	0.70	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.43	31.63	0.17	3.36	0.00	9.68	0.90	0.00	2.39	0.00
Trumbull 2009 (15 YZT optimal)	4	37.48	31.36	0.20	3.18	0.02	9.70	0.87	0.00	2.39	0.00
Trumbull 2009 (15 YZT optimal)	4	37.51	31.48	0.22	3.22	0.03	9.58	0.82	0.00	2.52	0.00
Trumbull 2009 (15 YZT optimal)	4	37.58	31.17	0.26	3.10	0.02	9.66	1.00	0.00	2.38	0.00
Trumbull 2009 (15 YZT optimal)	4	37.51	31.59	0.20	3.04	0.04	10.02	0.95	0.00	2.40	0.00
Trumbull 2009 (15 YZT optimal)	4	37.44	31.30	0.27	4.06	0.03	8.77	0.47	0.00	2.40	0.00
Trumbull 2009 (15 YZT optimal)	4	37.70	31.63	0.31	4.24	0.02	8.91	0.50	0.00	2.27	0.00
Trumbull 2009 (15 YZT optimal)	4	37.59	30.69	0.20	4.60	0.04	9.07	0.30	0.00	2.67	0.07
Trumbull 2009 (15 YZT optimal)	4	37.16	30.20	0.43	4.70	0.02	9.30	0.98	0.00	2.44	0.00
Trumbull 2009 (15 YZT optimal)	4	37.88	30.73	0.58	4.64	0.01	9.34	1.05	0.00	2.36	0.05
Trumbull 2009 (15 YZT optimal)	4	37.76	31.58	0.36	4.19	0.00	8.87	0.51	0.00	2.34	0.00
Trumbull 2009 (15 YZT optimal)	4	37.09	30.17	0.52	4.79	0.00	9.17	1.02	0.00	2.38	0.00
Trumbull 2009 (15 YZT optimal)	4	37.56	30.12	0.41	4.72	0.01	9.45	0.96	0.00	2.46	0.03
Trumbull 2009 (15 YZT optimal)	4	37.42	30.95	0.46	4.50	0.00	8.86	0.68	0.00	2.32	0.00
Trumbull 2009 (15 YZT optimal)	4	37.39	29.92	0.48	5.03	0.05	9.41	0.88	0.00	2.45	0.04
Trumbull 2009 (15 YZT optimal)	4	37.59	30.84	0.20	4.49	0.02	9.06	0.36	0.00	2.65	0.04
Trumbull 2009 (15 YZT optimal)	4	37.32	30.58	0.47	4.50	0.04	9.21	1.01	0.00	2.34	0.03

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.39	30.57	0.46	4.54	0.00	9.34	0.92	0.00	2.35	0.03
Trumbull 2009 (15 YZT optimal)	4	37.19	30.76	0.46	4.45	0.00	9.18	0.95	0.00	2.36	0.00
Trumbull 2009 (15 YZT optimal)	4	37.62	31.81	0.35	4.32	0.06	8.85	0.60	0.00	2.27	0.00
Trumbull 2009 (15 YZT optimal)	4	37.58	31.02	0.44	4.33	0.02	9.10	0.62	0.00	2.37	0.00
Trumbull 2009 (15 YZT optimal)	4	37.22	30.45	0.44	4.63	0.00	9.07	0.83	0.00	2.38	0.00
Trumbull 2009 (15 YZT optimal)	4	37.06	30.20	0.36	4.68	0.05	8.97	0.87	0.00	2.38	0.00
Trumbull 2009 (15 YZT optimal)	4	37.07	29.89	0.67	4.92	0.04	9.33	1.01	0.00	2.24	0.11
Trumbull 2009 (15 YZT optimal)	4	37.07	30.05	0.60	5.20	0.05	9.10	1.24	0.00	2.18	0.02
Trumbull 2009 (15 YZT optimal)	4	37.46	30.89	0.45	4.64	0.04	9.27	0.94	0.00	2.42	0.00
Trumbull 2009 (15 YZT optimal)	4	37.25	30.51	0.55	4.71	0.03	9.32	1.01	0.00	2.34	0.00
Trumbull 2009 (15 YZT optimal)	4	37.11	30.03	0.55	4.83	0.04	9.12	1.08	0.00	2.33	0.00
Trumbull 2009 (15 YZT optimal)	4	37.02	30.07	0.46	4.72	0.03	9.23	0.98	0.00	2.46	0.00
Trumbull 2009 (15 YZT optimal)	4	37.01	29.78	0.48	4.62	0.09	9.29	1.02	0.00	2.35	0.01
Trumbull 2009 (15 YZT optimal)	4	37.26	29.10	0.72	5.47	0.02	9.27	0.84	0.00	2.47	0.09
Trumbull 2009 (15 YZT optimal)	4	37.06	30.11	0.49	4.82	0.00	9.07	0.97	0.00	2.39	0.00
Trumbull 2009 (15 YZT optimal)	4	37.24	30.18	0.57	4.57	0.00	9.02	0.80	0.00	2.37	0.00
Trumbull 2009 (15 YZT optimal)	4	37.25	30.23	0.59	4.55	0.00	9.09	0.81	0.00	2.34	0.00
Trumbull 2009 (15 YZT optimal)	4	37.04	29.25	0.48	5.08	0.06	9.34	0.76	0.00	2.60	0.04
Trumbull 2009 (15 YZT optimal)	4	36.90	29.29	0.50	5.16	0.05	9.42	0.69	0.00	2.63	0.17
Trumbull 2009 (15 YZT optimal)	4	37.10	29.61	0.43	4.92	0.00	9.33	0.75	0.00	2.55	0.10
Trumbull 2009 (15 YZT optimal)	4	36.78	29.97	0.46	5.13	0.02	9.24	0.74	0.00	2.55	0.05
Trumbull 2009 (15 YZT optimal)	4	36.42	29.40	0.45	6.17	0.03	8.82	0.81	0.00	2.47	0.00
Trumbull 2009 (15 YZT optimal)	4	36.95	31.08	0.30	4.84	0.03	8.99	0.47	0.00	2.46	0.03

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	36.45	30.69	0.53	4.40	0.03	9.38	1.04	0.00	2.28	0.26
Trumbull 2009 (15 YZT optimal)	4	36.52	30.40	0.47	4.47	0.03	9.53	0.85	0.00	2.35	0.19
Trumbull 2009 (15 YZT optimal)	4	36.77	30.79	0.58	4.09	0.01	9.34	1.00	0.00	2.33	0.24
Trumbull 2009 (15 YZT optimal)	4	36.86	30.18	0.49	5.01	0.03	9.26	0.78	0.00	2.51	0.21
Trumbull 2009 (15 YZT optimal)	4	37.39	30.82	0.54	4.36	0.02	9.45	0.95	0.00	2.34	0.29
Trumbull 2009 (15 YZT optimal)	4	37.25	31.39	0.21	4.22	0.02	8.63	0.47	0.00	2.29	0.17
Trumbull 2009 (15 YZT optimal)	4	37.21	30.07	0.51	4.48	0.05	9.31	0.83	0.00	2.43	0.26
Trumbull 2009 (15 YZT optimal)	4	36.42	30.27	0.59	5.57	0.01	8.50	0.86	0.00	2.39	0.40
Trumbull 2009 (15 YZT optimal)	4	36.66	29.89	0.58	5.03	0.01	9.08	0.87	0.00	2.33	0.16
Trumbull 2009 (15 YZT optimal)	4	36.57	29.99	0.73	6.07	0.01	8.12	0.83	0.00	2.35	0.37
Trumbull 2009 (15 YZT optimal)	4	36.65	29.93	0.48	5.74	0.00	8.80	0.76	0.00	2.55	0.07
Trumbull 2009 (15 YZT optimal)	4	37.13	31.20	0.26	4.50	0.01	8.80	0.41	0.00	2.45	0.13
Trumbull 2009 (15 YZT optimal)	4	36.72	29.83	0.45	6.06	0.03	8.55	0.71	0.00	2.46	0.09
Trumbull 2009 (15 YZT optimal)	4	37.07	31.65	0.17	5.37	0.00	7.72	0.28	0.00	2.35	0.13
Trumbull 2009 (15 YZT optimal)	4	36.75	30.16	0.51	4.93	0.08	9.03	0.77	0.00	2.48	0.13
Trumbull 2009 (15 YZT optimal)	4	36.60	30.82	0.71	3.86	0.05	9.40	1.26	0.00	2.14	0.25
Trumbull 2009 (15 YZT optimal)	4	37.10	30.57	0.68	3.75	0.00	9.58	1.27	0.00	2.09	0.22
Trumbull 2009 (15 YZT optimal)	4	36.28	30.28	0.50	4.60	0.01	9.08	0.82	0.00	2.26	0.25
Trumbull 2009 (15 YZT optimal)	4	36.14	30.56	0.39	6.13	0.02	8.09	0.61	0.00	2.46	0.14
Trumbull 2009 (15 YZT optimal)	4	35.85	30.56	0.48	5.88	0.02	8.25	0.72	0.00	2.43	0.23
Trumbull 2009 (15 YZT optimal)	4	36.89	30.58	0.63	3.66	0.03	9.95	1.46	0.00	1.95	0.42
Trumbull 2009 (15 YZT optimal)	4	36.66	29.53	0.50	5.92	0.01	8.65	0.81	0.00	2.46	0.07
Trumbull 2009 (15 YZT optimal)	4	37.04	30.67	0.49	4.44	0.01	9.24	0.82	0.00	2.42	0.22

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.25	31.08	0.52	4.30	0.03	9.21	0.93	0.00	2.39	0.21
Trumbull 2009 (15 YZT optimal)	4	36.94	31.21	0.47	4.05	0.07	9.21	0.96	0.00	2.36	0.21
Trumbull 2009 (15 YZT optimal)	4	36.89	31.24	0.23	6.40	0.02	7.48	0.35	0.00	2.52	0.30
Trumbull 2009 (15 YZT optimal)	4	37.39	30.64	0.49	4.40	0.03	9.52	0.91	0.00	2.32	0.27
Trumbull 2009 (15 YZT optimal)	4	37.18	31.26	0.57	4.16	0.00	9.33	1.06	0.00	2.24	0.18
Trumbull 2009 (15 YZT optimal)	4	36.56	29.70	0.47	5.74	0.01	8.71	0.77	0.00	2.38	0.14
Trumbull 2009 (15 YZT optimal)	4	37.24	31.52	0.33	3.57	0.00	9.33	0.44	0.00	2.58	0.07
Trumbull 2009 (15 YZT optimal)	4	37.45	31.39	0.24	3.73	0.00	9.04	0.33	0.00	2.51	0.00
Trumbull 2009 (15 YZT optimal)	4	37.34	31.79	0.12	3.89	0.04	8.95	0.28	0.00	2.55	0.00
Trumbull 2009 (15 YZT optimal)	4	37.06	31.55	0.32	3.68	0.00	9.14	0.40	0.00	2.45	0.15
Trumbull 2009 (15 YZT optimal)	4	36.00	31.03	0.18	5.84	0.01	8.79	0.32	0.00	2.45	0.00
Trumbull 2009 (15 YZT optimal)	4	37.46	30.94	0.47	3.60	0.01	9.66	0.77	0.00	2.46	0.17
Trumbull 2009 (15 YZT optimal)	4	37.18	30.02	0.49	4.59	0.02	9.34	0.86	0.00	2.47	0.10
Trumbull 2009 (15 YZT optimal)	4	37.01	29.97	0.38	4.93	0.01	9.13	0.69	0.00	2.58	0.00
Trumbull 2009 (15 YZT optimal)	4	37.14	30.73	0.60	3.32	0.03	9.61	1.02	0.00	2.35	0.18
Trumbull 2009 (15 YZT optimal)	4	37.30	30.51	0.57	3.62	0.00	9.77	0.94	0.00	2.40	0.17
Trumbull 2009 (15 YZT optimal)	4	37.55	31.50	0.27	3.44	0.05	9.33	0.31	0.00	2.53	0.00
Trumbull 2009 (15 YZT optimal)	4	37.53	31.04	0.37	3.58	0.00	9.55	0.59	0.00	2.50	0.20
Trumbull 2009 (15 YZT optimal)	4	37.74	31.93	0.18	3.67	0.00	8.88	0.23	0.00	2.46	0.00
Trumbull 2009 (15 YZT optimal)	4	36.70	30.01	0.56	4.54	0.00	9.34	0.81	0.00	2.47	0.02
Trumbull 2009 (15 YZT optimal)	4	37.03	30.87	0.53	3.54	0.00	9.64	0.91	0.00	2.44	0.18
Trumbull 2009 (15 YZT optimal)	4	37.59	31.73	0.10	3.79	0.02	8.91	0.25	0.00	2.41	0.00
Trumbull 2009 (15 YZT optimal)	4	37.55	31.33	0.23	3.67	0.05	9.05	0.36	0.00	2.45	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.19	30.81	0.19	4.34	0.02	8.83	0.50	0.00	2.53	0.00
Trumbull 2009 (15 YZT optimal)	4	36.84	30.26	0.57	3.58	0.04	9.38	0.94	0.00	2.27	0.15
Trumbull 2009 (15 YZT optimal)	4	37.18	30.74	0.53	3.57	0.02	9.69	0.99	0.00	2.24	0.25
Trumbull 2009 (15 YZT optimal)	4	37.24	30.36	0.59	4.12	0.00	9.59	0.80	0.00	2.52	0.04
Trumbull 2009 (15 YZT optimal)	4	37.25	30.70	0.47	4.24	0.04	9.67	0.78	0.00	2.55	0.03
Trumbull 2009 (15 YZT optimal)	4	37.20	30.86	0.55	3.54	0.02	9.57	1.00	0.00	2.26	0.21
Trumbull 2009 (15 YZT optimal)	4	37.37	31.62	0.08	4.25	0.03	8.78	0.25	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	36.91	29.73	0.45	5.10	0.01	9.23	0.85	0.00	2.36	0.11
Trumbull 2009 (15 YZT optimal)	4	37.35	30.92	0.54	3.47	0.01	9.75	0.87	0.00	2.41	0.26
Trumbull 2009 (15 YZT optimal)	4	36.85	30.28	0.47	4.28	0.02	9.46	0.78	0.00	2.43	0.05
Trumbull 2009 (15 YZT optimal)	4	36.94	31.29	0.16	4.23	0.01	9.01	0.31	0.00	2.49	0.00
Trumbull 2009 (15 YZT optimal)	4	37.47	31.54	0.14	4.30	0.00	9.07	0.29	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.72	30.52	0.60	3.74	0.01	9.81	0.91	0.00	2.47	0.16
Trumbull 2009 (15 YZT optimal)	4	37.56	30.35	0.51	3.74	0.05	9.69	0.87	0.00	2.52	0.08
Trumbull 2009 (15 YZT optimal)	4	36.89	29.87	0.40	4.91	0.03	9.07	0.73	0.00	2.48	0.00
Trumbull 2009 (15 YZT optimal)	4	37.09	30.13	0.53	4.79	0.00	9.34	0.87	0.00	2.38	0.06
Trumbull 2009 (15 YZT optimal)	4	36.89	30.71	0.48	3.82	0.05	9.66	0.71	0.00	2.58	0.31
Trumbull 2009 (15 YZT optimal)	4	36.95	30.61	0.51	3.88	0.00	9.75	0.68	0.00	2.52	0.32
Trumbull 2009 (15 YZT optimal)	4	37.27	30.31	0.49	4.35	0.03	9.39	0.53	0.00	2.66	0.25
Trumbull 2009 (15 YZT optimal)	4	37.18	30.23	0.57	3.74	0.03	9.58	1.08	0.00	2.24	0.23
Trumbull 2009 (15 YZT optimal)	4	37.16	31.03	0.21	4.64	0.04	8.81	0.34	0.00	2.53	0.00
Trumbull 2009 (15 YZT optimal)	4	37.07	30.65	0.34	4.83	0.01	8.97	0.56	0.00	2.59	0.00
Trumbull 2009 (15 YZT optimal)	4	37.23	30.78	0.56	3.32	0.00	9.65	0.99	0.00	2.29	0.29

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.09	30.81	0.64	3.69	0.03	9.66	1.07	0.00	2.35	0.21
Trumbull 2009 (15 YZT optimal)	4	36.99	30.25	0.51	3.48	0.05	9.59	0.96	0.00	2.38	0.28
Trumbull 2009 (15 YZT optimal)	4	37.23	29.83	0.66	4.02	0.04	9.78	0.94	0.00	2.45	0.37
Trumbull 2009 (15 YZT optimal)	4	37.26	30.68	0.39	3.29	0.02	9.59	0.72	0.00	2.42	0.37
Trumbull 2009 (15 YZT optimal)	4	37.06	30.25	0.48	3.30	0.00	9.68	1.00	0.00	2.27	0.35
Trumbull 2009 (15 YZT optimal)	4	37.32	30.38	0.57	3.57	0.03	9.67	1.14	0.00	2.30	0.32
Trumbull 2009 (15 YZT optimal)	4	37.40	31.39	0.18	3.83	0.00	8.88	0.35	0.00	2.44	0.13
Trumbull 2009 (15 YZT optimal)	4	37.45	31.50	0.16	3.91	0.04	8.75	0.28	0.00	2.45	0.00
Trumbull 2009 (15 YZT optimal)	4	37.14	30.34	0.55	3.44	0.02	9.64	1.07	0.00	2.30	0.31
Trumbull 2009 (15 YZT optimal)	4	37.08	30.34	0.49	3.42	0.00	9.49	1.07	0.00	2.25	0.20
Trumbull 2009 (15 YZT optimal)	4	36.96	30.48	0.46	3.23	0.02	9.60	1.07	0.00	2.24	0.30
Trumbull 2009 (15 YZT optimal)	4	37.27	30.00	0.47	3.69	0.00	9.81	0.85	0.00	2.51	0.34
Trumbull 2009 (15 YZT optimal)	4	37.32	30.82	0.64	3.77	0.00	9.92	1.26	0.00	2.19	0.29
Trumbull 2009 (15 YZT optimal)	4	37.10	30.25	0.75	3.65	0.03	9.79	1.19	0.00	2.30	0.31
Trumbull 2009 (15 YZT optimal)	4	37.10	30.22	0.84	3.68	0.00	9.80	1.14	0.00	2.20	0.31
Trumbull 2009 (15 YZT optimal)	4	37.13	30.17	0.82	3.75	0.01	9.64	1.14	0.00	2.31	0.30
Trumbull 2009 (15 YZT optimal)	4	36.99	29.91	0.68	3.83	0.01	9.75	1.15	0.00	2.30	0.38
Trumbull 2009 (15 YZT optimal)	4	37.33	30.12	0.69	3.83	0.03	9.89	1.21	0.00	2.14	0.36
Trumbull 2009 (15 YZT optimal)	4	36.85	30.14	0.80	3.61	0.02	9.80	1.33	0.00	2.03	0.26
Trumbull 2009 (15 YZT optimal)	4	36.90	30.15	0.49	3.45	0.08	9.48	1.03	0.00	2.29	0.35
Trumbull 2009 (15 YZT optimal)	4	37.03	30.28	0.47	3.57	0.00	9.43	1.05	0.00	2.21	0.26
Trumbull 2009 (15 YZT optimal)	4	37.19	29.88	0.42	4.01	0.06	9.63	0.51	0.00	2.73	0.43
Trumbull 2009 (15 YZT optimal)	4	37.81	31.77	0.24	3.60	0.04	9.21	0.49	0.00	2.36	0.19

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	37.62	31.98	0.24	3.61	0.03	8.93	0.47	0.00	2.32	0.00
Trumbull 2009 (15 YZT optimal)	4	37.69	31.83	0.26	3.64	0.02	8.95	0.48	0.00	2.31	0.06
Trumbull 2009 (15 YZT optimal)	4	37.52	31.41	0.39	3.55	0.01	9.25	0.60	0.00	2.35	0.29
Trumbull 2009 (15 YZT optimal)	4	37.67	31.62	0.29	3.76	0.05	9.01	0.54	0.00	2.34	0.17
Trumbull 2009 (15 YZT optimal)	4	37.64	31.65	0.15	3.79	0.02	9.12	0.35	0.00	2.49	0.10
Trumbull 2009 (15 YZT optimal)	4	37.39	31.23	0.24	3.86	0.02	9.03	0.39	0.00	2.38	0.22
Trumbull 2009 (15 YZT optimal)	4	37.35	31.43	0.24	3.88	0.02	8.91	0.41	0.00	2.40	0.17
Trumbull 2009 (15 YZT optimal)	4	37.46	31.24	0.26	3.49	0.03	9.29	0.39	0.00	2.51	0.24
Trumbull 2009 (15 YZT optimal)	4	37.70	31.61	0.23	3.81	0.00	9.11	0.33	0.00	2.49	0.28
Trumbull 2009 (15 YZT optimal)	4	37.07	30.57	0.48	3.61	0.02	9.65	0.88	0.00	2.40	0.33
Trumbull 2009 (15 YZT optimal)	4	37.51	31.40	0.26	3.81	0.00	9.01	0.39	0.00	2.49	0.18
Trumbull 2009 (15 YZT optimal)	4	37.55	30.70	0.48	3.39	0.02	9.86	0.88	0.00	2.36	0.32
Trumbull 2009 (15 YZT optimal)	4	37.43	31.57	0.22	3.81	0.00	8.87	0.35	0.00	2.38	0.05
Trumbull 2009 (15 YZT optimal)	4	37.52	31.77	0.12	3.88	0.01	8.87	0.25	0.00	2.44	0.00
Trumbull 2009 (15 YZT optimal)	4	37.50	31.41	0.16	3.91	0.04	8.84	0.29	0.00	2.47	0.00
Trumbull 2009 (15 YZT optimal)	4	37.41	30.29	0.48	3.54	0.02	9.78	0.87	0.00	2.48	0.32
Trumbull 2009 (15 YZT optimal)	4	37.54	31.00	0.44	3.52	0.02	9.74	0.90	0.00	2.34	0.38
Trumbull 2009 (15 YZT optimal)	4	36.90	30.63	0.55	3.76	0.02	9.70	1.07	0.00	2.33	0.26
Trumbull 2009 (15 YZT optimal)	4	37.35	30.57	0.36	3.76	0.06	9.55	0.81	0.00	2.49	0.22
Trumbull 2009 (15 YZT optimal)	4	37.48	30.22	0.37	3.62	0.04	9.89	0.68	0.00	2.52	0.33
Trumbull 2009 (15 YZT optimal)	4	37.35	30.13	0.55	3.79	0.00	9.82	0.97	0.00	2.41	0.34
Trumbull 2009 (15 YZT optimal)	4	36.84	32.42	0.89	7.42	0.08	6.32	1.10	0.00	1.91	0.00
Trumbull 2009 (15 YZT optimal)	4	37.06	32.72	0.42	6.92	0.03	6.53	0.86	0.00	2.16	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	36.88	31.25	1.18	7.75	0.07	6.32	0.86	0.00	2.13	0.00
Trumbull 2009 (15 YZT optimal)	4	36.82	30.73	1.17	8.08	0.05	6.18	0.67	0.00	2.24	0.00
Trumbull 2009 (15 YZT optimal)	4	36.49	31.11	1.30	7.66	0.06	6.17	0.97	0.00	2.08	0.00
Trumbull 2009 (15 YZT optimal)	4	36.92	34.27	0.53	6.39	0.04	5.69	0.73	0.00	1.73	0.00
Trumbull 2009 (15 YZT optimal)	4	37.27	33.51	0.40	6.35	0.01	6.07	0.76	0.00	1.92	0.00
Trumbull 2009 (15 YZT optimal)	4	37.15	31.30	0.81	7.44	0.03	6.52	0.77	0.00	2.22	0.00
Trumbull 2009 (15 YZT optimal)	4	37.19	31.58	0.79	7.67	0.01	6.29	0.71	0.00	2.18	0.00
Trumbull 2009 (15 YZT optimal)	4	37.10	30.45	1.88	7.49	0.05	6.75	0.78	0.00	2.06	0.00
Trumbull 2009 (15 YZT optimal)	4	37.46	32.54	0.60	7.09	0.06	6.32	0.69	0.00	2.05	0.00
Trumbull 2009 (15 YZT optimal)	4	36.98	32.98	0.61	7.00	0.03	6.14	0.79	0.00	2.05	0.00
Trumbull 2009 (15 YZT optimal)	4	36.88	32.98	0.85	5.94	0.03	6.75	1.12	0.00	1.83	0.00
Trumbull 2009 (15 YZT optimal)	4	37.20	33.15	0.72	5.84	0.08	6.53	1.01	0.00	1.88	0.00
Trumbull 2009 (15 YZT optimal)	4	37.26	33.25	0.53	6.13	0.11	6.52	0.84	0.00	2.00	0.00
Trumbull 2009 (15 YZT optimal)	4	36.84	31.99	1.29	7.20	0.03	6.32	1.15	0.00	1.84	0.00
Trumbull 2009 (15 YZT optimal)	4	37.20	32.54	0.65	7.32	0.08	6.43	0.66	0.00	2.22	0.00
Trumbull 2009 (15 YZT optimal)	4	37.56	32.86	0.39	7.08	0.05	6.20	0.54	0.00	2.03	0.00
Trumbull 2009 (15 YZT optimal)	4	37.43	32.98	0.47	6.98	0.06	6.28	0.60	0.00	2.13	0.00
Trumbull 2009 (15 YZT optimal)	4	37.07	31.37	0.81	7.77	0.07	6.47	0.64	0.00	2.34	0.00
Trumbull 2009 (15 YZT optimal)	4	36.85	32.36	1.06	7.11	0.04	6.28	1.06	0.00	1.89	0.00
Trumbull 2009 (15 YZT optimal)	4	37.09	32.29	0.86	7.21	0.08	6.34	0.85	0.00	2.07	0.00
Trumbull 2009 (15 YZT optimal)	4	37.09	33.79	0.53	6.40	0.06	6.44	0.98	0.00	1.84	0.00
Trumbull 2009 (15 YZT optimal)	4	37.16	34.16	0.26	5.79	0.02	6.33	0.71	0.00	1.88	0.00
Trumbull 2009 (15 YZT optimal)	4	37.00	33.05	0.62	6.28	0.06	6.34	0.90	0.00	1.98	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Trumbull 2009 (15 YZT optimal)	4	36.89	32.73	0.59	6.46	0.03	6.51	0.90	0.00	2.11	0.00
Trumbull 2009 (15 YZT optimal)	4	36.79	32.54	0.64	6.69	0.05	6.52	0.80	0.00	2.01	0.00
Trumbull 2009 (15 YZT optimal)	4	36.70	33.60	0.54	6.26	0.01	6.35	0.94	0.00	1.95	0.00
Trumbull 2009 (15 YZT optimal)	4	37.10	32.93	0.66	6.86	0.04	6.34	0.93	0.00	2.00	0.00
Trumbull 2009 (15 YZT optimal)	4	37.12	33.10	0.77	6.36	0.06	6.37	1.06	0.00	1.86	0.00
VandenBleeken 2007 (15 YZT optimal)	4	37.27	34.70	0.19	10.62	0.07	2.13	0.03	0.00	0.76	0.01
VandenBleeken 2007 (15 YZT optimal)	4	37.20	35.06	0.13	10.53	0.08	2.27	0.02	0.00	0.71	0.00
VandenBleeken 2007 (15 YZT optimal)	4	36.78	34.92	0.14	10.99	0.09	2.12	0.02	0.00	0.64	0.00
VandenBleeken 2007 (15 YZT optimal)	4	36.89	34.31	0.09	9.55	0.04	3.54	0.01	0.00	0.95	0.00
VandenBleeken 2007 (15 YZT optimal)	4	36.58	34.02	0.15	10.39	0.07	2.99	0.03	0.00	0.88	0.00
VandenBleeken 2007 (15 YZT optimal)	4	36.51	33.97	0.10	11.27	0.10	2.55	0.04	0.00	0.89	0.00
VandenBleeken 2007 (15 YZT optimal)	4	37.42	34.08	0.06	10.17	0.08	2.96	0.02	0.00	0.88	0.01
VandenBleeken 2007 (15 YZT optimal)	4	36.88	34.40	0.10	9.48	0.14	3.42	0.06	0.00	0.91	0.00
VandenBleeken 2007 (15 YZT optimal)	4	36.55	30.12	0.49	9.68	0.05	6.09	0.23	0.00	2.06	0.04
Zacek (1998)	7	31.96	5.71	2.31	32.04	0.00	6.65	0.00	0.00	1.64	0.00
Zacek (1998)	7	32.66	7.71	1.46	29.21	0.00	7.95	0.00	0.00	2.13	0.00
Zacek (1998)	7	33.11	7.19	2.05	29.08	0.11	7.70	0.00	0.00	1.66	0.00
Zacek (1998)	7	32.12	5.15	3.48	32.47	0.00	6.24	0.00	0.00	1.58	0.00
Zacek (1998)	7	31.06	2.39	0.38	38.13	0.00	6.19	0.00	0.00	1.55	0.00
Zacek (1998)	7	32.17	2.93	1.26	36.17	0.00	7.02	0.05	0.00	1.48	0.00
Zacek (1998)	7	32.13	4.11	2.04	34.71	0.09	6.72	0.00	0.00	1.61	0.00
Zacek (1998)	7	32.41	6.57	2.20	31.68	0.10	6.72	0.00	0.00	1.82	0.00
Zacek (1998)	7	33.22	10.91	2.34	26.60	0.00	6.75	0.00	0.00	2.02	0.00
Zacek (1998)	7	36.46	24.58	1.67	12.18	0.00	7.85	0.00	0.00	3.05	0.00
Zacek (1998)	7	36.63	24.49	1.71	12.10	0.00	7.93	0.08	0.00	2.97	0.00

source	Numeric provenance class for R	SiO2	Al2O3	TiO2	Total as FeO	MnO	MgO	CaO	best Li2O - measured or calculated	Na2O	F
Zacek (1998)	7	37.35	28.15	0.12	7.98	0.08	9.37	0.34	0.00	2.91	0.00
Zacek (1998)	7	37.11	28.16	0.00	8.00	0.00	9.38	0.27	0.00	3.07	0.00
Zacek (1998)	7	37.20	28.49	0.08	7.69	0.00	9.39	0.32	0.00	3.03	0.00
Zacek (1998)	7	37.32	27.72	0.25	8.89	0.00	9.24	0.28	0.00	2.92	0.00
Zacek (1998)	7	37.58	30.17	0.22	6.21	0.00	9.22	0.14	0.00	3.05	0.00
Zacek (1998)	7	37.19	25.92	0.69	8.68	0.00	10.23	0.07	0.00	3.23	0.00
Zacek (1998)	7	36.78	26.13	0.49	8.25	0.00	10.40	0.34	0.00	3.11	0.00
Zacek (1998)	7	36.37	26.32	0.49	9.77	0.00	9.26	0.00	0.00	3.02	0.00
Zacek (1998)	7	31.46	2.90	0.79	36.46	0.00	6.36	0.24	0.00	1.47	0.00
Zacek (1998)	7	31.78	2.62	1.15	34.67	0.09	7.87	0.00	0.00	1.98	0.00
Zacek (1998)	7	31.10	2.71	2.66	34.94	0.00	5.62	0.00	0.00	1.81	0.00
Zacek (1998)	7	30.24	2.76	3.44	33.21	0.15	5.85	0.00	0.00	1.62	0.00
Zacek (1998)	7	33.79	13.96	3.60	21.43	0.00	7.38	0.00	0.00	2.73	0.00
Zacek (1998)	7	33.64	14.03	3.32	21.64	0.00	7.44	0.00	0.00	2.60	0.00
Zacek (1998)	7	34.18	14.82	3.56	20.69	0.19	7.77	0.07	0.00	2.81	0.00
Zacek (1998)	7	36.29	26.90	0.22	8.52	0.00	9.33	0.10	0.00	3.02	0.00
Zacek (1998)	7	36.61	29.56	0.17	9.96	0.00	6.86	0.16	0.00	2.91	0.00
Zacek (1998)	7	37.03	26.64	0.51	8.33	0.00	9.71	0.00	0.00	3.03	0.00

APPENDIX D – VIATOR DATA TABLE

This data was taken from Viator (2003). Each entry is an individual chemical analysis of a tourmaline. They are arranged alphabetically by author. The ‘provenance class’ column is which of the 8 provenance classes it was assigned in Forest J.

Forest J provenance classes are provided here for faster reference.

1	Granites, pegmatites and aplites, Li-poor
2	Pegmatites, granites and aplites, Li-rich
3	Pegmatites, granites and aplites, Li-rich with calcareous host
4	Metapelites and metapsammities
5	Calcareous
6	Meta-mafic
7	Meta-evaporites
8	Hydrothermal

Information on Lithium content is not often directly measured (e.g., in a wet chem analysis), so this was calculated according to the Pesquera method.. If a specimen had both measured lithium content and calculated lithium content, the greater value was used. Iron content is given in terms of FeO.

Analysis/Sample	Provenance Class	Number	SiO2	Al2O3	TiO2	FeO	MnO	MgO	CaO	Li2O	Na2O	F
bhsc3a	1	3	35.39	32.74	0.42	9.42	0.09	4.37	0.2	0	1.99	0.11
bhsc3a	8	4	35.51	33.05	0.27	9.13	0.02	4.29	0.18	0	1.89	0.11
bhsc3a	8	5	34.81	33.52	0.06	12.39	0.18	1.55	0.07	0.38194	1.52	0
bhsc3a	1	15	34.21	33.46	0.26	11.98	0.15	2.04	0.11	0	1.82	0
bhsc3a	4	17	36.63	31.19	0.67	5.97	0.02	7.62	0.29	0	2.18	0
bhsc3a	4	18	36.7	30.32	0.59	5.77	0	8.58	0.42	0	2.32	0
bhsc3a	1	19	35.25	33.44	0.31	11.92	0.21	2.37	0.17	0	1.75	0
bhsc3a	1	20	35.4	33.76	0.09	11.21	0.17	2.61	0.13	0	1.78	0
bhsc3a	1	22	35.47	33.42	0.2	11	0.13	2.9	0.13	0	1.76	0
bhsc3a	1	23	34.79	33.41	0.07	12.4	0.14	2.11	0.14	0	1.73	0
bhsc3a	8	41	34.57	33.08	0.26	12.5	0.2	1.83	0.1	0.3826	1.67	0
bhsc3a	1	42	34.65	33.01	0.27	11.95	0.09	2.56	0.14	0	1.77	0
bhsc3a	8	44	35.54	29.43	0.75	10.25	0.02	5.74	0.4	0	1.91	0
bhsc3a	4	45	35.52	33.06	0.78	6.58	0.02	6.38	0.47	0	1.86	0
bhsc3a	1	46	33.98	33.7	0.18	13.52	0.23	0.62	0.08	0.048	1.74	0.09
bhsc3a	1	47	35	33.11	0.47	10.38	0.11	3.61	0.16	0	1.86	0.08
bhsc3a	4	48	36.48	31.9	0.61	5.67	0.02	7.8	0.85	0	1.89	0
bhsc3a	2	49	34.86	33.34	0.14	13.55	0.36	0.82	0.07	0.17428	1.51	0
bhsc3a	8	50	35.69	32.93	0.64	7.7	0	5.97	0.51	0	1.82	0
bhsc3a	8	51	35.06	29.89	0.17	10.85	0.03	5.19	0.02	0	2.24	0
bhsc3a	8	52	34.29	35.38	0.61	7.07	0.02	7.12	0.47	0	2.29	0
bhfc4	8	50	35.09	33.08	0.81	8.1	0	5.15	0.37	0	1.71	0
bhfc4	1	51	34.28	32.86	0.12	12.49	0.16	2.05	0.1	0	1.64	0
bhfc4	8	52	34.23	33.16	0.48	9.45	0.05	3.89	0.14	0	1.89	0
bhfc4	8	53	35.37	32.8	0.66	7.71	0.02	5.75	0.4	0	1.94	0.06
bhfc4	4	55	35.86	32.8	0.9	6.47	0.02	6.53	0.72	0	1.76	0
bhfc4	8	56	35.34	32.68	0.45	7.75	0.08	5.52	0.33	0	1.91	0
bhfc4	4	57	35.17	32.75	1.01	6.43	0.05	6.59	1.51	0	1.27	0
bhfc4	8	59	35.16	34.52	0.2	7.93	0.07	4.69	0.08	0	1.72	0
bhfc4	4	60	35.38	32.94	0.34	5.98	0.03	6.49	1.43	0	1.15	0
bhfc4	4	61	35.17	34.15	0.31	5.95	0.04	6.17	1.21	0	1.33	0
bhfc4	4	62	35.44	32.88	0.73	5.9	0.01	6.61	0.57	0	1.74	0
bhfc4	1	65	35.64	31	0.73	10.59	0.1	4.43	0.16	0	1.92	0.11

Analysis/Sample	Provenance Class	Number	SiO2	Al2O3	TiO2	FeO	MnO	MgO	CaO	Li2O	Na2O	F
bhfc4	8	66	36.31	33.1	0.41	3.93	0.06	7.85	0.3	0	2.09	0.26
bhfc4	8	67	35.3	32.57	0.64	8.28	0.07	5.29	0.26	0	2.01	0.24
bhfc4	1	68	35.43	30.86	0.46	10.46	0.09	4.58	0.16	0	2.04	0.1
bhfc4	1	69	35.02	33.75	0.85	9.26	0.11	3.66	0.15	0	1.78	0
bhfc4	4	70	35.97	33.07	0.36	5.18	0.08	6.97	0.18	0	2.05	0.1
bhfc4	4	71	36.38	32.85	0.42	4.74	0.11	7.73	0.36	0	2.22	0.36
bhfc4	1	72	35.36	31.08	0.65	9.63	0.12	5.13	0.15	0	2.13	0.08
bhfc4	8	73	36.22	33.03	0.5	6.98	0.02	5.85	0.32	0	1.89	0
bhfc4	8	74	36.73	32.29	0.32	8.68	0.06	5.63	0.05	0	2.11	0
bhfc4	8	75	36.27	32.43	0.95	7.79	0.02	5.48	0.11	0	1.79	0
bhfc4	4	76	36.18	33.82	0.68	4.57	0.03	7.55	1.11	0	1.72	0
bhfc4	4	77	36.67	31.63	0.46	8.25	0.06	6.87	0.66	0	1.98	0
bhfc4	4	81	35.21	33.15	0.52	6.44	0.02	6.15	1.17	0	1.26	0
bhfc4	8	91	35.68	33	0.47	8.89	0.09	4.68	0.24	0	1.84	0
bhfc4	8	92	35.78	32.88	0.44	8.9	0.06	4.73	0.23	0	1.83	0
bhfc4	4	94	34.34	32.06	1.12	7.74	0.04	5.81	1.55	0	1.32	0
bhfc4	4	95	34.37	32.11	1.01	7.5	0.07	6.01	1.51	0	1.36	0
bhfc4	8	97	35.93	30.91	0.49	8.35	0.01	6.3	0.25	0	2.04	0
bhfc4	8	98	35.35	32.55	0.62	8.82	0.07	4.72	0.22	0	1.91	0
bhfc4	8	99	35.5	32.45	0.53	7.73	0.08	5.71	0.31	0	1.97	0
bhfc4	1	100	34.92	33.55	0.18	11.04	0.13	2.74	0.05	0	1.44	0
bhfc4	8	101	34.85	33.02	0.8	9.47	0.06	4.33	0.27	0	1.78	0
bhfc4	8	102	35.05	33.83	0.26	9.8	0.07	3.5	0.14	0	1.54	0
bhfc4	4	103	35.49	32.93	1.13	6.24	0.07	6.18	0.49	0	1.76	0
bhfc4	8	7	34.82	33.37	0.21	10.66	0.17	2.78	0.17	0	1.68	0
bhfc4	8	8	34.64	33.01	0.67	9.15	0.07	4.25	0.27	0	1.73	0
bhfc4	4	9	34.64	32.84	0.92	6.35	0.04	6.06	0.74	0	1.57	0
bhfc4	4	10	35.46	33.75	0.35	6.04	0.08	5.9	0.54	0	1.37	0
bhfc4	8	11	34.78	33.23	0.73	8.62	0.04	4.53	0.27	0	1.77	0
bhfc4	8	12	35	31.95	0.42	8.82	0.07	4.67	0.27	0	1.86	0
bhfc4	8	15	34.73	32.87	1.01	8.01	0.02	4.94	0.58	0	1.53	0
bhfc4	8	16	34.96	31.73	0.84	7.58	0.03	5.49	0.89	0	1.48	0
bhfc4	4	17	34.8	33.44	0.58	4.79	0.02	6.6	1.27	0	1.37	0

Analysis/Sample	Provenance Class	Number	SiO2	Al2O3	TiO2	FeO	MnO	MgO	CaO	Li2O	Na2O	F
bhfc4	8	19	34.32	33.05	0.21	11.67	0.08	2.57	0.15	0	1.69	0
bhfc4	8	20	35.69	31.09	1.19	7.26	0.05	5.63	0.21	0	1.67	0
bhfc4	4	21	34.51	33.56	0.97	5.91	0.01	5.96	1.03	0	1.47	0
bhfc4	4	23	34.74	32.74	0.75	7.04	0.02	5.57	1	0	1.38	0
bhfc4	4	26	35.27	33.72	0.1	10.07	0.14	2.88	0.07	0	1.29	0
bhfc4	4	27	34.7	32.66	0.75	5.59	0.03	6.28	0.7	0	1.62	0
bhfc4	4	30	34.8	32.04	0.76	5.78	0.03	6.28	0.58	0	1.66	0
bhfc4	8	31	34.44	32.97	0.34	11.22	0.01	2.9	0.21	0	1.77	0
bhfc4	8	32	35.09	32.14	0.71	7.83	0.09	4.96	0.15	0	1.82	0
bhfc4	4	33	35.99	32.53	0.69	5.5	0.03	6.62	1.01	0	1.32	0
bhsc3a	2	2	35.5	33.86	0.06	12.21	0.17	1.63	0.05	0.46002	1.55	0
bhsc3a	1	3	34.99	33.91	0.26	11.58	0.1	2.63	0.13	0	1.8	0
bhsc3a	8	4	34.8	33.65	0.38	9.32	0.09	4.11	0.2	0	1.92	0
bhsc3a	2	5	35.35	33.84	0.06	12.63	0.21	1.55	0.05	0.3626	1.43	0
bhsc3a	1	6	34.26	33.78	0.35	11.64	0.17	2.18	0.1	0	1.89	0
bhsc3a	4	8	35.36	32.22	0.64	7.04	0.03	6.08	0.41	0	1.89	0
bhsc3a	4	9	35.38	31.99	0.74	7.11	0.04	6.33	0.57	0	1.88	0
bhsc3a	4	10	35.5	30.38	0.72	6.25	0.03	7.86	0.79	0	2.02	0
bhsc3a	4	11	35.3	28.99	0.76	8.07	0.05	7.65	0.68	0	2.24	0
bhsc3a	4	12	35.04	28.5	0.76	7.85	0.05	7.84	0.99	0	2.13	0
bhcr1	4	70	35.25	33.66	0.7	6.64	0.03	6.12	1.05	0	1.4	0
bhcr1	4	71	35.63	32.75	0.86	6.13	0.03	6.69	0.61	0	2	0
bhcr1	4	72	35.35	32.67	0.83	6.79	0.02	6.32	0.75	0	1.9	0
bhcr1	6	73	34.95	30.9	1.27	4.99	0.11	8.2	1.81	0	1.56	0
bhcr1	8	76	35.87	32.05	1.11	8.38	0.09	5.2	0.13	0	1.85	0
bhcr1	8	77	35.64	33.21	0.78	7.42	0	5.95	0.49	0	1.89	0
bhcr1	8	78	36.18	31.89	0.7	8.93	0.03	5.19	0.41	0	1.78	0
bhcr1	8	79	35.94	32.63	0.81	8.03	0.02	5.52	0.53	0	1.82	0
bhcr1	8	80	34.68	34.62	0.5	6.67	0	5.73	1.34	0	1.33	0
bhcr1	4	81	34.94	33.29	0.96	6.96	0.08	6.22	1.09	0	1.57	0
bhcr1	8	82	35.29	33.23	1.11	7.67	0.03	5.32	0.51	0	1.82	0
bhcr1	8	86	35.15	33.53	0.51	7.03	0.01	5.48	0.61	0	1.61	0
bhcr1	8	90	34.68	33.69	0.25	13.02	0.12	1.83	0.12	0.24283	1.64	0

Analysis/Sample	Provenance Class	Number	SiO2	Al2O3	TiO2	FeO	MnO	MgO	CaO	Li2O	Na2O	F
bhcr1	8	91	35.36	31.95	0.78	9.18	0.01	5.1	0.45	0	1.7	0
bhcr1	8	92	35.59	33.21	0.42	8.65	0.06	5.14	0.32	0	1.78	0
bhcr1	1	93	34.36	32.78	0.35	14.23	0.14	1.46	0.23	0.09464	1.72	0
bhcr1	8	94	34.4	32.33	0.53	14.1	0.13	1.65	0.25	0.17881	1.68	0

VITA

Erin Walden is a Baton Rouge native and attended McKinley High School in Baton Rouge, where she was president of the Art Club and active in theatre. She graduated in 2000 and immediately entered Louisiana State University with plans to double major in English and Mass Communication, but withdrew from the university upon her father's sudden death in November 2000. She returned to Louisiana State University in the spring of 2004 and received a Bachelor of Science in Geology in December 2008.

Erin entered the Master's degree program at Louisiana State University in 2010 to study under Darrell Henry. She married her husband Jonathan in April 2012. When she was not combing through tourmaline analyses, she enjoyed cooking and writing genre fiction.