LA-UR- 07-2258

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Intended for: New Mexico Geological Society
Albuquerque, NM
September, 2007
New Mexico Geological Society, Field Conference, Guidebook

Los Alamos NATIONAL LABORATORY EST.1943

COMPARISON OF TWO SYSTEMS OF NOMENCLATURE FOR THE TSHIREGE MEMBER, BANDELIER TUFF, CENTRAL PAJARITO PLATEAU, NEW MEXICO

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INTRODUCTION

The thick stack of ignimbrites that make up the Tshirege Member of the Bandelier Tuff is divided into subunits that form widespread mappable units across the Pajarito Plateau. Two classifications systems, one developed by Rogers (1995) and the other by Broxton and Reneau (1995), are widely used by various authors in this guidebook to describe Tshirege subunits. As an aid to the reader attempting to correlate tuffs between the two systems of nomenclature, subunits of the Tshirege Member are described using unit designations of Rogers followed by that of Broxton and Reneau (e.g. Unit A/Qbt 1g), where correlative. Figure 1 shows correlations between the two classification schemes.

SETTING

The Bandelier Tuff has two members, each consisting of a basal pumice fall overlain by a petrologically related succession of ash-flow tuffs (Bailey et al., 1969) erupted from separate, but nearly coincident, calderas. The lower Otowi Member (1.61 Ma; Izett and Obradovich, 1994 and Spell et al., 1996) was erupted from the Toledo caldera; the upper Tshirege Member (1.22 Ma; Izett and Obradovich, 1994; Spell et al.,

1996) was erupted from the Valles caldera. Deposits of Bandelier Tuff form broad tuff plateaus (Pajarito on the east and Jemez on the west) that dip away from the central volcanic highlands. The Pajarito Plateau is made up of Bandelier Tuff that flowed more than 21 km across the western Española basin. The cliff-forming Tshirege Member, a multiple-flow, ash-and-pumice sheet, is the most widely exposed bedrock unit of the Pajarito Plateau (Fig. 1). It is generally over 60 m thick in the north-central part of the Los Alamos National Laboratory (LANL) and is over 185 m thick in the southern part.

GENERAL CHARACTERISTICS OF THE TSHIREGE MEMBER

The Tshirege Member is comprised of multiple flow units whose boundaries are defined by surge deposits, horizontal partings, and zones of pumice accumulation. Welding generally increases up section suggesting that deeper and hotter parts of the magma chamber were progressively tapped as the Tshirege Member was erupted (Smith and Bailey, 1966). The Tshirege Member is largely made up of high-silica rhyolite, but the latter stages of eruption produced low- to medium-silica rhyolite. Compositional zonation is particularly evident for trace elements; early-erupted tuffs contain the highest concentrations of incompatible elements such as U, Th, Pb, Li, and Rb, whereas tuffs erupted later are enriched in Ti and Ba, and Sr (e.g. Smith and Bailey, 1966). Phenocrysts make up 12 to 23% of the rock (uncorrected for porosity) and consist predominantly of sanidine and quartz with trace amounts of plagioclase ± hornblende ± clinopyroxene ± orthopyroxene ± fayalite. Anothoclase also occurs in the uppermost subunits.

The Tshirege Member was described as a compound cooling unit by Smith (1960a,b) and Smith and Bailey (1966). Time breaks between the successive emplacements of ash-flow units caused the tuff to cool as at least four distinct cooling units (Broxton and Reneau, 1995) that display variable physical properties vertically and horizontally. These variations in physical properties reflect zonal patterns of varying degrees of compaction, welding, and glass crystallization. The welding and crystallization zonation in the Tshirege Member produce vertical variations in properties such as density, porosity, hardness, composition, color, and surface weathering patterns. The degree of welding in each of the cooling units generally decreases from west to east, reflecting higher emplacement temperatures and thicker deposits closer to the Valles caldera.

Rogers (1995 and this volume) sees the Tshirege as a single cooling unit, a compound cooling unit, which is not subdivisible into separate simple cooling units. A compound cooling unit shows an interrupted cooling history. The cooling unit concept is based on three zones of welding with four superimposed zones of crystallization. A conceptual model, such as Smith's cooling unit, assumes predictability and infers "standard" vertical and lateral changes. There seems to be little disagreement that the Tshirege ash flows show a highly variable degree of welding from place to place and in all directions. For this reason, Rogers (1995 and this volume) chose to subdivide the Tshirege based on flow boundaries which separate lithologies which are different from those above or below.

DESCRIPTIONS OF SUBUNITS

The Tsankawi Pumice Bed forms the base of the Tshirege Member. Where exposed, it is commonly 50 to 75 cm thick. This pumice-fall deposit contains sorted pumice lapilli (diameters reaching about 6.4 cm) in a crystal-rich matrix. Several thin ash beds are interbedded with the pumice-fall deposits.

Unit A/Qbt 1g overlies the Tsankawi Pumice Bed and consists of porous, nonwelded, and poorly sorted ash-flow tuffs. The "g" in the Broxton and Reneau designation stands for "glass" because volcanic glass in shards and pumices is unaffected by devitrification or vapor phase alteration. Unit A/Qbt 1g is poorly indurated, but it forms steep cliffs because a resistant bench near the top of the unit forms a hard, protective cap over the softer underlying tuffs (Fig. 1B). A thin (10 to 25 cm), pumice-poor, pyroclastic surge deposit is sometimes present at the base of this subunit.

Unit B/Qbt 1v forms alternating cliff-like and sloping outcrops composed of porous, nonwelded, but crystalline tuffs. The "v" in the Broxton and Reneau designation stands for vapor-phase crystallization that together with crystallization of glass in shards and pumices (devitrification) transformed the rock matrix into microcrystalline aggregates of silica polymorphs and sanidine. The base of this unit is a thin, horizontal zone of preferential weathering that marks the abrupt transition from glassy tuffs below to crystallized tuffs above. This feature forms a widespread mappable horizon (locally called the vapor-phase notch by some and by others a flow boundary) throughout the Pajarito Plateau. In some locations the vapor-phase notch grades laterally into a prominent bench developed on top of the glassy tuff (Fig. 1A and 1B). The lower part of this subunit (designated Qbt 1vc by Broxton and Reneau) is a colonnade tuff that is orange brown, resistant to weathering, and has distinctive columnar cooling joints. The upper part of the unit (designated Qbt 1vu by Broxton and Reneau) consists of white, variably compacted, alternating cliff- and slope-forming tuffs.

Unit C/Qbt 2 forms a distinctive, medium brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter colored tuffs above and below (Fig. 1A and

1B). A series of surge beds commonly mark its base in the eastern part of LANL, but these surge deposits cannot be traced to the west. In the central and western part of LANL, the boundary between Unit C/Qbt 2 and Unit B/Qbt 1v is gradational and the distinction between the two units is somewhat arbitrary. Unit C/Qbt 2 is typically the most strongly welded tuff in the Tshirege Member. Welding tends to increase up section through the subunit. On the western side of the plateau, borehole density logs show a partial cooling break in the middle of the densely welded portion of the unit. Unit C/Qbt 2 is characterized by lower porosity and higher density relative to the other units of the Tshirege Member, and because of its brittle nature, it contains abundant joints. Vapor-phase crystallization of flattened shards and pumices is extensive in this subunit.

Unit D/Qbt 3 is a nonwelded to partly welded, vapor-phase altered tuff that forms the cap rock of mesas in the central part of the Pajarito Plateau (Fig. 1B). Its base consists of purple-gray, unconsolidated, porous, crystal-rich, nonwelded tuff that underlies a broad, gently sloping bench developed on top of strongly welded Unit C/Qbt 2. This basal, nonwelded portion forms relatively soft outcrops that weather into low, rounded outcrops with a white color, which contrast with the partly-welded, cliff-forming tuffs in the upper portions of the subunit. Unit D/Qbt 3 becomes moderately to densely welded in the western part of LANL (Fig. 1C). In the extreme western part of LANL, the upper part of Qbt 3 and an additional subunit, Qbt 3t, are included within Unit E of Rogers (Fig. 1A, 1C). Qbt 3t is a local unit of limited distribution comprised of moderately to densely welded ash-flow tuff that has petrographic and geochemical characteristics transitional between Unit D/Qbt 3 and Unit E/Qbt 4 (Gardner et al., 2001).

Unit E/Qbt 4 is a complex unit consisting of nonwelded to densely-welded ash-flow tuffs. The lower part of the subunit is made up of nonwelded to partly-welded ash-flow tuffs characterized by small, sparse pumices and intercalated surge deposits. The upper part of the subunit includes pumiceous, densely-welded ash-flow tuffs that that form mesa cap rocks in the western part of the plateau; this caprock tuff is designated Unit F by Rogers (Fig. 1C). Devitrification and vapor-phase alteration are typical in this subunit, but thin zones of vitric ash-flow tuff occur locally. The occurrence of these tuffs is limited to the western half of the Pajarito Plateau. Lewis et al. (2002) divide these heterogeneous tuffs into local subunits and provide detailed descriptions of them.

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FIGURE CAPTIONS

FIGURE 1: Subunits of the Tshirege Member of the Bandelier Tuff. (A) Idealized stratigraphic section correlating subunits of Rogers (1995) and Broxton and Reneau (1995). Broxton and Reneau subunits modified to include Qbt 3t as described by Gardner et al., (2001). (B) Photograph of middle and lower Tshirege Member subunits in lower Pueblo Canyon (background) and tributary (foreground). View looking northwest. (C) Middle and upper Tshirege subunits in upper Water Canyon. View looking northwest.

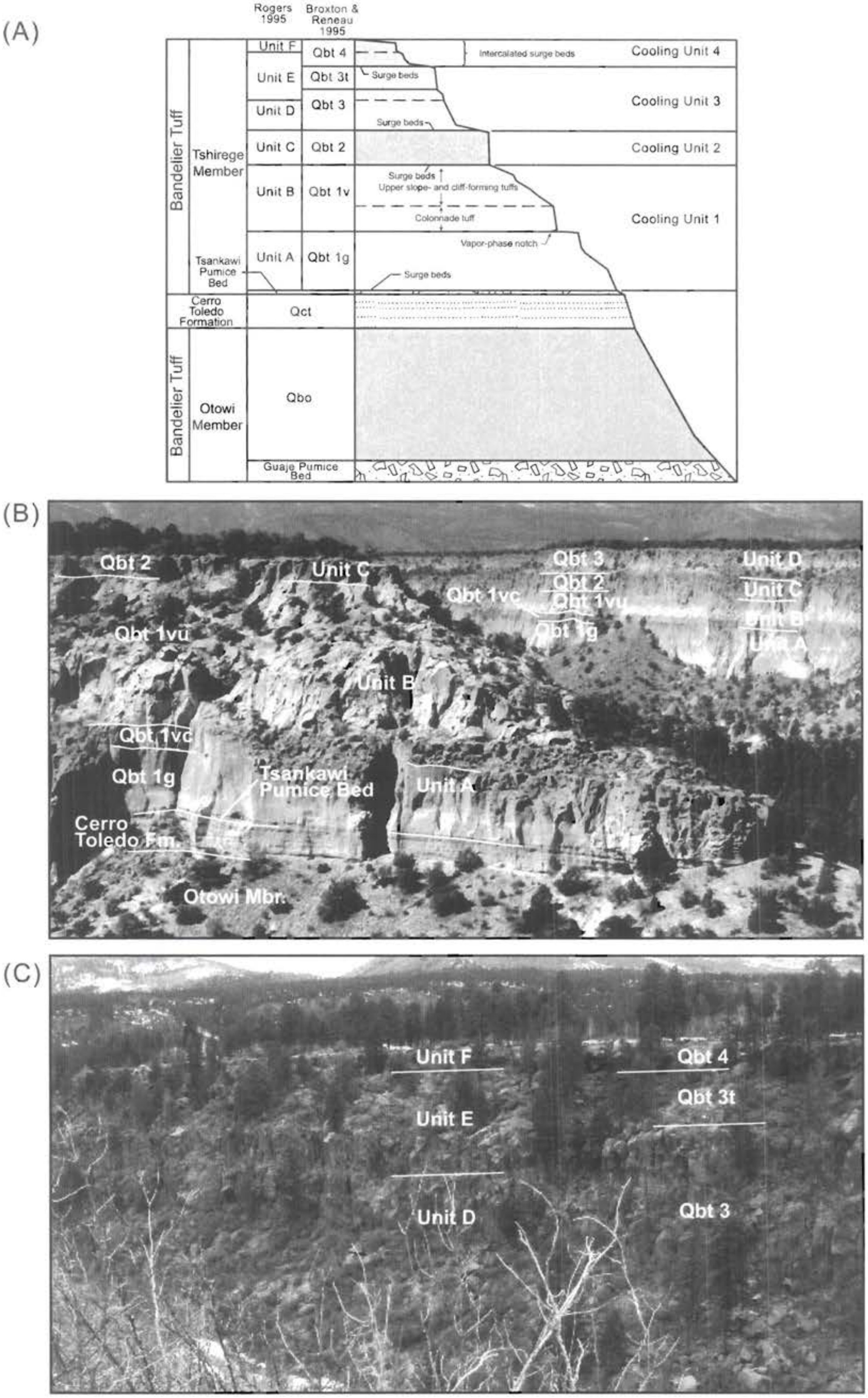
(A)
Rogers 1995
Broxton & Reneau 1995
Bandelier Tuff
Tshirege Member
Tsankawi Pumice Bed
Unit F
Unit E
Unit D
Unit C
Unit B
Unit A
Qbt 4
Qbt 3t
Qbt 3
Qbt 2
Qbt 1v
Qbt 1g
Intercalated surge beds
Surge beds
Upper slope- and cliff-forming tuffs
Colonnade tuff
Vapor-phase notch
Cooling Unit 4
Cooling Unit 3
Cooling Unit 2
Cooling Unit 1
Cerro Toledo Formation
Qct
Otowi Member
Qbo
Guaje Pumice Bed
(B)
Qbt 2
Unit C
Qbt 3
Qbt 2
Qbt 1vc
Qbt 1vu
Qbt 1g
Unit D
Unit C
Unit B
Unit A
Qbt 1vu
Unit B
Qbt 1vc
Qbt 1g
Tsankawi Pumice Bed
Unit A
Cerro Toledo Fm.
Otowi Mbr.
(C)
Unit F
Qbt 4
Qbt 3t
Unit E
Unit D
Qbt 3

Figure 1