YUCCA MOUNTAIN STRATIGRAPHIC AND MODEL UNIT CORRELATION CHART

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QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: CNWRA data contained in this report meet quality assurance requirements described in the CNWRA Quality Assurance Manual. Data used in support of this report are taken from documents published by U.S. Department of Energy contractors and supporting organizations; the respective source of these non-CNWRA data should be consulted for determining the level of quality assurance.

ANALYSES AND CODES: No software used in the preparation of this report required maintenance in accordance with CNWRA Technical Operating Procedure (TOP)–018.

1 BACKGROUND

Yucca Mountain comprises a several kilometer-thick accumulation of volcanic tuff deposited on an irregular surface of eroded and deformed Paleozoic and Precambrian basement composed of highly faulted and folded sedimentary and metasedimentary rocks. The tuff originated from a series of Middle to Late Miocene (15–9 million years) calderas that collectively form what has been defined as the southwestern Nevada volcanic field. Rocks of the Paintbrush Group, principally the Tiva Canyon Tuff (12.7 million years), make up the main surface exposures of Yucca Mountain. Younger tuffs related to the Timber Mountain Group are locally exposed at Yucca Mountain in topographic lows between large block-bounding faults. Alluvium and colluvium, mainly derived from erosion of the Miocene tuffs exposed on fault-bound ridges, also fill the topographic lows and basins. The potential repository horizon is within the underlying Topopah Springs Tuff (12.8 million years) of the Paintbrush Group. The Paintbrush Group tuffs rest on a sequence of older tuffs, including the Prow Pass and Bullfrog formations of the Crater Flat Group.

The rock units of the southwestern Nevada volcanic field were first described by Ball (1907). Hinrichs and Orkild (1961) were the first to define stratigraphy relevant to Yucca Mountain. Their work, northeast of Yucca Mountain's present day surface facilities, led to the initial understanding of the volcanic stratigraphy and the geologic and tectonic evolution of the area. Their work also provided the basis for a series of detailed mapping efforts targeted specifically at the Yucca Mountain block, including the work of Scott and Bonk (1984). The nomenclature of Scott and Bonk (1984) is still included in correlation tables of model layer unit designations. Sawyer, et al. (1994) provide the most recent comprehensive regional stratigraphy of the Miocene volcanic rocks in the Yucca Mountain region. Potter, et al. (2002) and Dickerson and Drake (2006) provide the most recent detailed geologic maps of Yucca Mountain.

The Miocene volcanic strata at Yucca Mountain have been investigated extensively by the U.S. Department of Energy (DOE) and its subcontractors and consultants in order to fully characterize the rock units and as a basis for the development of detailed process-level and performance assessment models of the potential repository at Yucca Mountain. The initial efforts by the U.S. Geological Survey focused on detailed lithostratigraphy, which is a classification based on the age relationship and physical characteristics of rock units, such as layering, color, or composition. Since the development of the original lithostratigraphy, a variety of alternative classifications have been developed depending on the specific purpose and application of the classification to discipline-specific Yucca Mountain studies. These alternatives include (i) model layers for the Geologic Framework Model (Bechtel SAIC Company, LLC, 2004a); (ii) hydrostratigraphic units used in saturated zone flow and transport models, such as the DOE Hydrogeologic Framework Model for the Saturated Zone Site Scale Flow and Transport Model or HFM–27 (Bechtel SAIC Company, LLC, 2004b); (iii) rock units used in unsaturated flow and transport analyses models, such as Bechtel SAIC Company, LLC (2004c,d); and (iv) thermal-mechanical units for use in geomechanical analyses (Ortiz, et al., 1985). Because the nature of volcanic tuff strata is complex, these alternative stratigraphies do not easily correlate with the known lithostratigraphy. As a result, a comprehensive and transparent review of the DOE information may be complicated by potential inconsistencies or omissions among and between the various classifications.

2 PURPOSE

The purpose of this report is to (i) provide staff with the necessary information and tools to rapidly and effectively review and evaluate rock and model unit correlation across technical disciplines (e.g., stratigraphic, hydrologic, and geomechanical); (ii) provide a condensed and comprehensive summary of available DOE information related to the detailed classification of rock and model units at Yucca Mountain; and (iii) in the prelicense period, resolve discrepancies and clarify ambiguities among the numerous stratigraphic systems developed by the DOE and its supporting organizations. As a result of the synthesis, a Yucca Mountain Stratigraphic and Model Unit Correlation Chart (YMCC)[1] (plate 1) was developed. This chart provides a detailed summary of the most relevant and recent stratigraphic information used by DOE across the DOE program.

The DOE stratigraphic and model units have changed as new and more detailed lithostratigraphic information has developed and more detailed computer models have evolved. Therefore, this compilation is a status report, subject to further changes.

3 SCOPE

In order to focus specifically on the site of the potential Yucca Mountain repository, the scope of this report and associated YMCC focuses on the Miocene volcanic stratigraphy that make up the Yucca Mountain block. Younger Quaternary sedimentary and volcanic units, as well as older Paleozoic and Precambrian bedrock strata, are shown as superadjacent and subadjacent boundaries. Based on additional review and analysis of DOE information, these other geologic units may be included in future revisions of the YMCC.

In an effort to limit the size of the chart, only the detailed unit abbreviations from the 2000 Yucca Mountain Site Description (CRWMS M&O, 2000a) were used. These detailed unit abbreviations are used in DOE's various analyses and process models' stratigraphic correlation tables to indicate which units are considered part of that model's layers units. The YMCC's youngest unit used for correlation purposes is the Timber Mountain Group. This unit is also the youngest unit for most of the analyses and process models incorporated in the chart.

4 DESCRIPTION

The foundation of the YMCC is Table 7-1 and Table 7-9 from the Yucca Mountain Site Description (Bechtel SAIC Compay, LLC, 2004e). These tables are very much equivalent to Tables 4.5-1, 4.5-2, and 4.8-1 of the 2000 Yucca Mountain Site Description (CRWMS M&O, 2000a), but do not contain the same level of stratigraphic unit description. This level of detail is useful in determining the correlation of grouped units from DOE analysis and process model reports and was consulted when clarifying unit groupings. However, only the stratigraphic unit abbreviation of the 2000 Yucca Mountain Site Description (CRWMS M&O, 2000a) is included in the YMCC and is used for the correlation of the more recently released DOE analysis and process model reports. The informal unit nomenclature, based on Scott and Bonk (1984), was extracted from Table 7-9 and included in the YMCC as an independent column. The unit

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[1]Yucca Mountain Stratigraphic Model Unit Correlation Chart (YMCC) (plate 1) is referred to repeatedly in this report; consequently, the term YMCC will be used to designate the chart throughout this report.

symbols of Buesch, et al. (1996, Table 2) that proposed stratigraphic nomenclature were placed next to the Scott and Bonk (1984) column to initiate chronological order and to focus first on the geologic lithostratigraphy. These two columns form the foundation of lithostratigraphic descriptions and designations. Continuing the geologic stratigraphy, all columns from Table 6-2 of the GFM2000 (Bechtel SAIC Company, LLC, 2004a), the volcanic units and unit thicknesses based on borehole data from Table 3-1 of Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e), and the geologic stratigraphy of Table 7-9 in the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e) were included in YMCC.

The next focus of the YMCC is unsaturated zone flow unit designations. Columns with either detailed and major hydrogeologic units or detailed and 2002 UZ Flow Model layer units [Tables 7-1 and 7-9 of the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e), Table 6-5 from Development of Numercial Grids for UZ Flow and Transport Modeling (Bechtel SAIC Company, LLC, 2004c), and Table 1 from Flint, et al., (2006)], as well as the 2004 UZ model units and hydrogeologic units of Table 6.1-1 of the UZ Flow Models and Submodels (Bechtel SAIC Company, LLC, 2004d) were incorporated in the YMCC to illustrate the various interpretations of unit designations. The Thermal Mechanical Units column was added to the YMCC from Table 3-5 of the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e). The Rock Properties Model Units (Bechtel SAIC Company, LLC, 2004f) column and the Mineralogic Model Units (Bechtel SAIC Company, LLC, 2004g) column were also incorporated into the YMCC. The final column added, but placed as the first column in the YMCC, is the Unit Age column taken from Figure 2-8 in the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e).

The detailed unit abbreviations column from the 2000 Yucca Mountain Site Description (CRWMS M&O, 2000a), described earlier, was inserted again at the end of the YMCC. The intention of repeating the column is to facilitate horizontal referencing across the chart. The unit abbreviations in these two columns are in red print as an aid for unit location. Colored shading of every other formation is also used to assist in horizontal correlation across the YMCC. Another benefit of using color in the YMCC is that the stratigraphic and model unit group designations are more obvious.

The YMCC units included from the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e, Table 7-9) were formatted with the Group, Formation, and Member placed vertically, if space permitted, as well as horizontally. The dashed lines and arrows indicate that those units (group, formation, member, etc.) listed would be considered as one unit if the DOE report did not differentiate the individual units. The subgroup stratigraphic units in the YMCC have been indented to facilitate easy identification of associations between units. The group and formation stratigraphic units are in bold print for easy recognition. The amount of horizontal or vertical space given a stratigraphic or model unit does not represent the actual thickness of the unit. Unit thicknesses are located in the YMCC as a column from Table 3-1 of the Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e).

The authors of the YMCC did not add stratigraphic units to a YMCC column to make it consistent with the stratigraphic units included from a different table represented in another column [i.e., Rhyolite of Vent Pass is not listed as a unit in the Geologic Framework Model (Bechtel SAIC Company, LLC, 2004a)]. Stratigraphic and model unit correlations in the YMCC are made from the unit name used in the DOE report. If a unit name was not correlatable, a correlation using the unit description was considered (see plate 1 superscript description for ‡ and §). If the DOE analysis and process model report had a blank area in its stratigraphic or model unit table, that space in the YMCC contains a note to that effect. A space in the YMCC may also contain a note that the stratigraphic unit was (obviously) undifferentiated in the DOE stratigraphic table.

Model units may have the same unit abbreviation as the stratigraphic unit; however, the model unit will be either all capitalized letters or all lowercase letters as represented in the DOE table. These model units do not necessarily include the same subunits as indicated for the stratigraphic units. An example is the Tpy stratigraphic unit abbreviation for the Yucca Mountain Tuff Formation and the TPY hydrogeologic unit abbreviation.

Because one of the goals of the YMCC is to enable staff to easily identify source or reference information, each column header of the YMCC has an abbreviated reference callout, which corresponds to the complete reference information in the "Chart References" at the bottom of the YMCC. These complete references have listed beneath them, by table or figure title, the source reference cited in the DOE report. If full reference information was available for the cited source, it was also included (alphabetically) in the YMCC "Chart References."

Superscripts are used in the YMCC to inform the user of an uncertainty in the correlation of a unit or an explanation of the unit nomenclature [see ‡Tptf, Buesch, et al. (1996, Table 2)]. Had the correlation of hydrogeologic units been identical from one column to another in the YMCC, only the most recent report would be included and the later report recognized by a superscript in the column header information.

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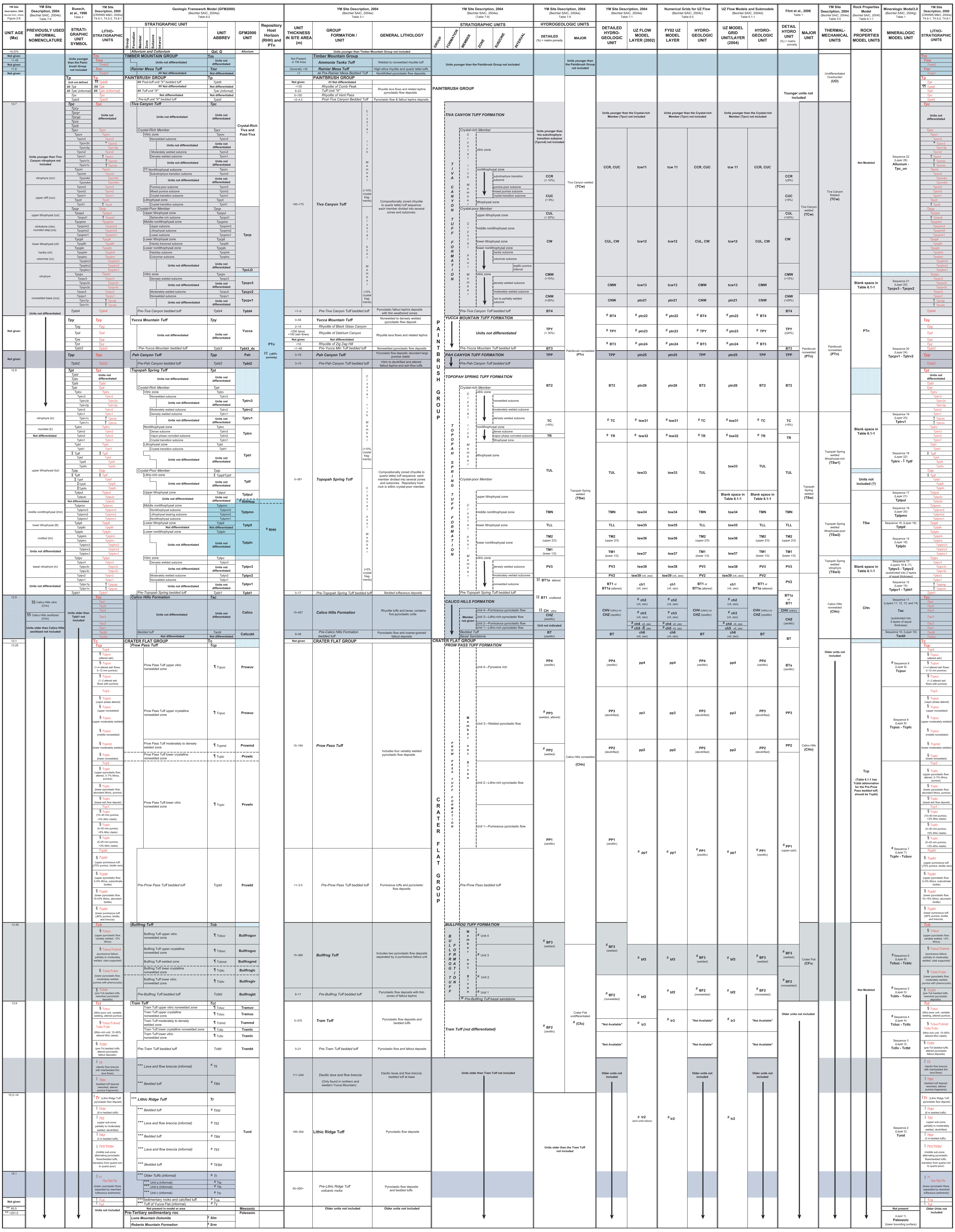
Plate 1. Yucca Mountain Stratigraphic and Model Unit Correlation Chart



Note: Hachured boxes in the Geologic Framework Model (GFM2000), Rock Properties Model (RPM2004), and Mineralogic Model (MM3.0), "units indicate 'header' lines for subdivided units", per the individual reports.

SYMBOL REFERENCES

* Yucca Mountain Site Description 2000, (CRWMS M&O, 2000a) has the same unit abbreviation for the Tiva Canyon nonwelded subzone and the nonwelded interval for that subzone of the crystal-rich vitric member.

† Table 4.5-2 of the Yucca Mountain Site Description 2000, (CRWMS M&O, 2000a) has a lower case "L" where a "1" is used in all other Tables included here.

‡ Buesch, et al., (1996), Open-File Report 94-469, Table 2 repeats the Lithic-rich zone, subzone and interval abbreviations (Tptf, Tptrf, Tptrfl and Tptrfn) for the zone, subzone, and interval within the crystal-poor member (Tptp). Tptf defines a lithic-rich zone. The contact between the overlying crystal-rich member and the underlying crystal-poor member is within the interior of the lithic-rich zone. The correct symbols should be Tptf, Tptpf, Tptpfl, and Tptpfn; per Yucca Mountain Site Description 2000 (CRWMS M&O, 2000a), Table 4.5-2.

§ Unit description from Table 4.5-1 and Table 4.5-2 (CRWMS M&O, 2000a); source of lithostratigaphic units and descriptions given as Moyer and Geslin (1995) for the Prow Pass Tuff; Spengler, et al., (1981) pp. 83–84 and Spengler and Chormack (1984) pp. 25–26 for the Bullfrog Tuff; and Carr, et al., (1986), Spengler, et al., (1981), Maldonado and Koether (1983), and Scott and Castellanos (1984) pp. 34, 36–37 for the Tram Tuff. Unit symbol given in Table 4.8-1 (CRWMS M&O, 2000a); source of lithostratigraphic description given as Geologic Framework Model 3.1 (CRWMS M&O 2000b). Direct correlation of the Bullfrog Tuff and the Tram Tuff between Table 4.5-1 and 4.8-1 (CRWMS M&O, 2000a), is not possible with this information.

‖ Unit description from Table 4.5-1(CRWMS M&O, 2000a); source of lithostratigaphic units and descriptions given as study of borehole G-1 (Spengler, et al., 1981, p. 36–39) Unit symbol given in Table 4.8-1 (CRWMS M&O, 2000a); source of lithostratigraphic description given as DTN: MO9510RIB00002.004 [YMP Reference Information Base Item: Stratigraphic Characteristics; Geologic/Lithologic Stratigraphy (1996)] (CRWMS M&O, 1997a). Descriptions given do not permit unit correlation.

¶ Geologic Framework Model 2000 (Bechtel SAIC Company, LLC, 2004c) and Geologic Framework Model 3.1 (CRWMS M&O, 2000b) (Geologic Framework Model 3.1 not included in the Yucca Mountain Stratigraphic and Model Unit Correlation Chart), references subdivision of the Crater Flat Group into six zones to accommodate needs of Geologic Framework Model users as given in Buesch and Spengler (1999, p. 62–64); only a direct correlation of Prow Pass Tuff properties is represented in the publication.

\# Not able to directly correlate to stratigraphic units.

** Age added from Geologic Time Scale (Gradstein and Ogg, 2004)

†† Table 6-2 of Geologic Framework Model 2000 (Bechtel SAIC Company, LLC, 2004c) labels this unit a subzone—should be zone.

‡‡ See page 3-32, 2004 Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e) for explanation.

§§ Units do not correlate to Scott and Bonk (1984).

‖‖ Discrete unit divisions not given.

¶¶ Unit symbol from Table 4.8-1 (CRWMS M&O, 2000a); source given as DTN: MO9510RIB00002.004 [YMP Reference Information Base Item: Stratigraphic Characteristics; Geologic/Lithologic Stratigraphy (1969)] (CRWMS M&O, 1997a).

\#\# Model stratigraphic units [e.g., Table 6-2 (Bechtel SAIC Company, LLC, 2004c) and Table 4.8-1 (CRWMS M&O, 2000a)] correlates the Tuff unit "X" (Tpki) to the rhyolite of Comb Peak per Table 2 of Buesch, et al., 1996; however, Table 2 (Buesch, et al., 1996) describes the rhyolite lava flows and related tephra of the Rhyolite of Comb Peak as Tpk and the older pyroclastic flows tentatively correlated with the rhyolite of Comb Peak as Tuff unit "X" (Tpki). It is unclear if the Post-tuff unit "X" bedded tuff (Tpbt6) is equivalent to the Pre-Rainier Mesa Tuff bedded tuff (Tmbt1). MO9510RIB00002.004 (CRWMS M&O, 1997a), source indicated for multiple tables, lists Tpbt6 in the Yucca Mountain Stratigraphic Nomenclature table but not the Tmbt1 bedded tuff; it does describe the Tmbt1 unit but not the Tpbt6 bedded tuff.

*** These hierarchical stratigraphic relationships do not coincide with Section 3.3.4.5, page 3-15 of the 2004 Yucca Mountain Site Description (Bechtel SAIC Company, LLC, 2004e).

CHART REFERENCES

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Table 6-2: Correlation Chart for Model Stratigraphy
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Table 3-1: Generalized Stratigraphic Column of Tertiary Volcanic Rocks in the Yucca Mountain Site Area (pp. T3-1 and T3-2)
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- **Crystal-rich and Crystal-poor member subdivions** of Tiva Canyon Tuff and Topopah Spring Tuff described in: **CRWMS M&O, 2000a**,Yucca Mountain Site Description (YMSD2000), Table 4.5-2, p. T4.5-4 through T4.5-16; based on: **Buesch, D.C., et al.**, 1996, Proposed Stratigraphic Nomenclature and Macroscopic Identification of Lithostratigraphic Units of the Paintbrush Group Exposed at Yucca Mountain, USGS OFR 94-469, Table 2, pp. 5–8.

Table 3-5: Comparison of Several Stratigraphic Subdivisions of Mid-Tertiary Volcanic Rocks at Yucca Mountain (pp. T3-6 and T3-7)
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Table 7-1: Lithostratigraphy, Hydrogeologic Unit, and Unsaturated Zone Flow Model Layer Correlation (pp. T7-1 and T7-2)
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Table 7-9: Generalized Lithostratigraphy, Previously Used Informal Stratigraphic Nomenclature, and Corresponding Detailed and Major Hydrogeologic Units at Yucca Mountain (pp. T7-8 and T7-9)
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