NEVADA BUREAU OF MINES AND GEOLOGY

Prepared in cooperation with the U.S. Geological Survey

MAP 135 GEOLOGIC MAP OF THE WILLOW CREEK RESERVOIR QUADRANGLE, ELKO COUNTY, NEVADA

GEOLOGIC MAP OF THE WILLOW CREEK RESERVOIR QUADRANGLE, ELKO COUNTY, NEVADA

Alan R. Wallace
2003

[Notes: All $^{40}Ar/^{39}Ar$ dates were calculated using a 27.55 Ma age for Fish Canyon Tuff (see table 1). All major-oxide and trace-element data are listed in table 2.]

Qaf **Artificial fill (Holocene)** Man-made deposits. Shown only at Willow Creek Reservoir dam.

Qal **Alluvium (Quaternary)** Alluvium forms unconsolidated alluvial deposits along stream bottoms and terraces adjacent to Willow and Ivanhoe Creeks and small tributaries, and isolated deposits along small streams in the southern part of the quadrangle. Alluvium is composed of unsorted silt, sand, and gravel. Terrace deposits are 1- to 2-m-thick along Willow Creek and up to 4 m thick along the upper reaches of Ivanhoe Creek. Dark soil and sagebrush vegetation are well-developed on terrace deposits, and sediments generally are visible only where modern streams have incised into those deposits.

Qc **Colluvium (Quaternary)** Colluvium occurs as unconsolidated talus and downslope wash that are derived primarily from rhyolite porphyry (Trp) and gravel deposits (QTg). Colluvium largely is developed on and covers tuffaceous sedimentary rocks (Tts, Ttsu, Ttsl). The unit grades into unit QTcs (colluvium and subcrops) in the north-central part of quadrangle.

Qls **Landslide deposits (Quaternary)** Deposits include chaotic to coherent slump blocks and megabreccia. Topography is hummocky above chaotic deposits. The deposits most commonly formed where rhyolite porphyry domes (Trp) overlie tuffaceous sedimentary rocks (units Tts, Ttsl). In the lower Ivanhoe Creek drainage, downslope surficial movement has filtered the surface of tuffaceous rocks (Ttsl) with pebble- to boulder-sized clasts of rhyolite porphyry.

QTg **Gravel (Quaternary and Pliocene?)** Unconsolidated, poorly sorted deposits of pebbles to boulders cap the pediment north of Willow Creek, and form isolated deposits along Ivanhoe Creek and southwest of Big Butte. Clasts are subrounded and composed almost entirely of Paleozoic chert and quartzite, with rare clasts of dacite and andesite of possibly Tertiary age. North of Willow Creek, downslope mass wasting of tuffaceous sedimentary rocks produced widespread redistribution of clasts on top of tuffaceous rocks (Qc).

QTcs **Colluvium and subcrops (Quaternary and Tertiary)** As exposed in the north-central part of the quadrangle southwest of the "Willow" survey point, very thin but widespread colluvial deposits (derived primarily from unit Trp) incompletely overlie poorly exposed subcrops of tuffaceous sedimentary rocks (Ttsl, Tvt, and Ttsu). The resulting exposures are an intimate mix between colluvium and subcrops.

Tuffs and Tuffaceous Sedimentary Rocks (Miocene)

Includes subaqueously and subaerially deposited tuffs and lesser fluvial clastic sediments that form a conformable stratigraphic section. The entire section is exposed along north shore of Willow Creek Reservoir. The units represent continuous sedimentation, but divisions were made to facilitate mapping and structural interpretation. The lower tuff (Ttsl) is below the andesite (Ta), the middle tuff (Ttsm) is between the andesite and vitric tuff (Tvt), and the upper tuff (Ttsu) is above the vitric tuff. The upper, middle, and lower tuff units largely are indistinguishable, especially with typically poor exposures; undifferentiated unit (Tts) includes tuffaceous rocks (Ttsl, Ttsm, Ttsu) where neither the andesite nor vitric tuff is present to provide stratigraphic divisions, or where isolated exposures of tuff preclude inclusion in a specific unit. The middle tuff unit is included in the lower tuff unit east of Ivanhoe Creek where andesite is absent. "Upper Tuff" and "Lower Tuff" of Bartlett and others (1991) included tuffs above and below the andesite, respectively. Due to the absence of the andesite east of Ivanhoe Creek, the laterally persistent vitric tuff is defined there as the division between lower (Ttsl, Ttsm) and upper (Ttsu) tuff units. Poor exposures in the southeastern third of quadrangle preclude more detailed division of tuff units and identification of possible faults. The sequence was deposited between about 16.5 and 14.4 Ma.

Tts **Tuffs and tuffaceous sedimentary rocks, undivided** Undifferentiated tuffaceous units (Ttsu, Ttsm, Tvt, and Ttsl) where poor and scattered exposures obscure further stratigraphic division; dotted "contacts" with those units show the approximate level of confidence in unit designation. In the basin east of Big Butte, extensive subcrops of tuffaceous sedimentary rocks are weathered and covered by a thin veneer of windblown silt; that area was mapped as unit Tts, although Ttsu, Tvt, and Ttsl all may be present in that area.

Ttsu **Upper tuffs and tuffaceous sedimentary rocks** Includes tan to gray, massive to finely bedded, very poorly exposed waterlain tuffs and tuffaceous sedimentary rocks. As exposed along Willow Creek Reservoir shoreline and in limited road and mine cuts, the basal units are composed of very thin-bedded water-laid deposits. In the southwest part of quadrangle, the contact with the vitric tuff unit is a water-laid tuff intermixed with a residual rubble lag deposit of vitric tuff clasts. Along the northeast shore of Willow Creek Reservoir, the basal beds show evidence of chaotic soft-sediment deformation. The age of the tuff bed near the base of the unit at the reservoir was estimated using tephrochronology at 15.05±0.25 Ma (table 1; Perkins and others, 1998). Unit Ttsu is correlative in part with the lower member of Carlin Formation exposed to the south and southeast, where it is 14.4-15.1 Ma (table 1; Fleck and others, 1998; Wallace, 2003a). The total thickness of the unit in this quadrangle is unknown due to poor exposures and faulting; it exceeds 400 m in the Santa Renia Fields Quadrangle (fig. 1; Theodore and others, 1998). Excessively thick sections shown on the map may indicate fault repetition.

Tcss **Carlin Formation, siltstone and sandstone member** Poorly exposed, tan siltstone and sandstone beds are exposed in a small area in the extreme southeast corner of the quadrangle. The sediments were deposited on the Vinini Formation. The beds are continuous with more extensive beds to the south and southeast, and the unit designation is based on continuity with mapped units in the Santa Renia Fields Quadrangle (Theodore and others, 1998). In the Willow Creek Reservoir SE Quadrangle (Wallace, 2003a), this unit is correlative with part of the upper tuff unit (Ttsu). In the northeastern part of that quadrangle, the unit overlies the Vinini Formation and is interfingered with the Craig rhyolite.

Tvt **Vitric tuff** The vitric tuff unit is a dark-brown, gray, to black, fine-grained, moderately welded vitric tuff. It compositionally is a rhyolite (71% SiO_2, Na_2O+K_2O=8.9%). Phenocrysts include plagioclase, sanidine, quartz, and pigeonite, with minor opaque minerals (fig. 2). The groundmass is composed of flattened, black, porous vitric ash. On weathered surface, felsic mineral phenocrysts form a distinctive, white-on-black speckled pattern. Near Willow Creek Reservoir, the tuff is massive to platy, forms resistant outcrops and ridges, and includes a dense, 0.5- to 1-m-thick basal vitrophyre; in the southwest part of the quadrangle, the unit is more friable and crops out poorly, but it forms a distinctive surface float. Welding indicates subaerial deposition, but the unit's apparent absence in the southeastern part of quadrangle may reflect subaqueous deposition, making it indistinguishable from other water-laid tuffs (Wallace, 2000, 2003b; see discussion in accompanying text). The overall thickness decreases to the south from >15 m to 1-3 m, with minor, local thickness variations due to irregularities in the topography at the time of eruption. $^{40}Ar/^{39}Ar$ date on sanidine of 15.10±0.06 Ma (table 1).

Ttsm **Middle tuffs and tuffaceous sedimentary rocks** These fine-grained tuffaceous units are shown only in the western part of the quadrangle, as explained above. The unit was replaced, usually completely, by white chalcedonic silica, masking most sedimentary features but making it a distinct marker unit in areas with otherwise poor exposures. As exposed in the Hollister Mine 2 km south of quadrangle (fig. 1), the unit is composed of thin-bedded, water-laid tuffaceous sediments (Wallace, 2003a). The thickness varies from a few to more than 10 m. Where the andesite is not present, the middle tuffaceous unit is included in the lower tuffaceous unit (Ttsl; see explanation above).

Ttsl **Lower tuffs and tuffaceous sedimentary rocks** The lower tuffaceous unit includes interbedded subaqueous to subaerial air-fall tuffs, reworked tuffaceous material, and minor sandstone and conglomerate. The unit unconformably overlies Eocene trachyandesitic flow units (Tta) at Willow Creek Reservoir and Eocene welded tuffs (Tbc) along Ivanhoe Creek. The unit is weakly indurated and very poorly exposed except along gullies and the reservoir shoreline. Identifiable phenocrysts vary in mineralogy throughout section, and they include quartz, sanidine, plagioclase, pyroxene, hornblende, and biotite. The basal third of the section is composed of tan, orange, to light-gray air-fall ash and pumice tuff, with siltstone, sandstone, pebble conglomerate, and minor diagenetic chert; conglomerate beds contain subrounded pebbles and cobbles of dacite and andesite, possibly derived from the Tuscarora Mountains area to the northeast (fig. 1). The middle third of the section is composed of water-laid, very finely bedded to massive air-fall tuffs, locally with abundant pumice; beds are white, light gray, black, to tan. The ash is extremely fresh and not reworked. The upper third of the section is composed of olive-green, massive to coarsely bedded ash-rich tuffs with thin white tuffaceous interbeds; this part of the section forms deeply weathered, dark olive-brown soil and does not crop out except along the shoreline of the reservoir. The total thickness of the unit is obscured by faulting, but it exceeds 200 m along the north shore of the reservoir. Excessively thick sections shown on map may indicate fault repetition. The unit designation in some areas with no exposed stratigraphic control is based on company-confidential drilling data. Plagioclase from a tuff bed near the middle of the section along the north shore of Willow Creek Reservoir produced a $^{40}Ar/^{39}Ar$ date of 15.84±0.10 (table 1).

Trp **Rhyolite porphyry (Miocene)** Rhyolite exposed in crystal-rich, coalescing domes and flows in the eastern two-thirds of the quadrangle. Composition: 77% SiO_2, Na_2O+K_2O=8.1%. Rocks are reddish-brown on weathered surfaces and gray-brown on fresh surfaces. Phenocrysts consist of quartz and sanidine, with subordinate plagioclase and rare pigeonite and opaque minerals (fig. 2); the groundmass is devitrified. The domes are composed of outward-dipping flows derived from central vents. The flows are planar to chaotically flow lobed near dome margins. The dome margins contain abundant vertical gas-escape structures and miarolitic cavities lined with euhedral quartz and minor topaz and fluorite. The rhyolite contains 12 to 16 ppm Sn (table 2). The dome east of the mouth of Ivanhoe Creek was dated at 14.92±0.05 Ma ($^{40}Ar/^{39}Ar$ date on sanidine; table 1).

Trpi **Rhyolite porphyry intrusive rocks** The dikes intruded the rhyolite porphyry domes and tuffaceous sedimentary rocks. Contacts between dike and dome rocks are vague. Phenocrysts in the dikes are identical to those in the rhyolite domes and flows (Trp).

Trv **Rhyolite of Velvet area (Miocene)** Reddish-brown, complexly flow-banded and flow-folded rhyolite flows are exposed along the southern edge of the quadrangle. They are more extensive south of the quadrangle, where the flows in part overlie the middle tuffaceous unit (Ttsm) (Wallace, 2003a). The rhyolite contains abundant small quartz phenocrysts (fig. 2), and the groundmass is partially to completely devitrified. Lithophysal flow tops are common. Composition: 75% SiO_2, Na_2O+K_2O=9.1%. Flows in this quadrangle dated at 15.10±0.05 Ma ($^{40}Ar/^{39}Ar$ date on sanidine; table 1).

Tcr **Craig rhyolite (Miocene)** Reddish brown, generally massive rhyolite flows are exposed in the southeastern part of the map area; they are more extensive to the south and southeast (Wallace, 2003a; Theodore and others, 1998). Phenocrysts include 2- to 10-mm sanidine and smaller quartz, plagioclase, and opaques, with trace amounts of pyroxene (fig. 2); the total phenocryst percentage and ratios of phenocrysts vary considerably from flow to flow. The groundmass is devitrified. Quartz phenocrysts prominent in chalcedony-replaced flows. Composition: 75% SiO_2, Na_2O+K_2O=7.7%. Dates on flows to south and southeast range from 14.99±0.05 to 15.16±0.05 Ma (Theodore and others, 1998; Wallace, 2003a). The unit was named informally by Bartlett and others (1991).

Ta **Andesite (Miocene)** Reddish to locally black andesite flow units are exposed in the west-central part of the quadrangle. The flows compositionally ranges from low-silica andesite to low-alkali basaltic trachyandesite (56-59% SiO_2, Na_2O+K_2O=3.0-6.4%; Na_2O, K_2O subequal). The flows usually are poorly exposed, but they form ubiquitous float of red, aphyric chips and larger platy slabs. Where exposed, the flow units are massive at the base and vesicular near the top. Phenocrysts are sparse and include plagioclase, olivine, and minor clinopyroxene (fig. 2). The unit thins to the east, grading from massive red flows to thin vesicular black flows, and it is not present east of Ivanhoe Creek. The thickness varies from 3 to 30 m, suggesting eruption onto an irregular paleosurface. The absence of hyaloclastic breccias and basal water hydration suggests subaerial emplacement.

Trc **Rock Creek rhyolite (Miocene)** Red, brittle, flow-banded rhyolite (75% SiO_2, Na_2O+K_2O=8.1%) flows are exposed in the western part of the map area and were encountered by drilling in the same area (Bartlett and others, 1991). The flows contain sparse, small (<1 mm) phenocrysts (<3% of rock) of sanidine, plagioclase, and pyroxene, and abundant thin gas vesicles are aligned parallel to bedding. Thin flow bands are laminar to contorted with isoclinal folding; mesoscopic folds are common. Weathering along flow bands produced platy outcrops. The flows are interbedded with the lower tuffaceous unit, based on surface and drilling data. Flows in this quadrangle are a distal part of a thick, extensive suite of rhyolite flows west of the quadrangle, where they underlie the andesite and all tuffaceous units (A. Wallace, unpub. mapping, 2000-2001). The unit was named informally by Bartlett and others (1991).

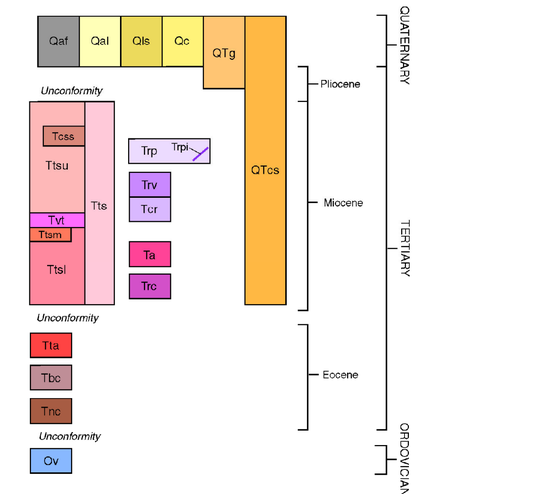
Tta **Trachyandesite flows and tuffs (late Eocene)** Dark-brown trachyandesite flows and interbedded tuffs form resistant outcrops in the Willow Creek area. The flows range in composition from trachyandesite to low-silica, low-alkali trachydacite (59-63% SiO_2, Na_2O+K_2O=6.8-7.7%; Na_2O-K_2O). The unit is composed of multiple flow units with an altered, leucocratic, tuffaceous and brecciated zone near the middle of the unit. Flows locally exhibit flow foliation and ramp structures, but the otherwise are massive; flow tops were autobrecciated in places. Outcrops are massive to vaguely sheeted parallel to bedding. Phenocrysts include plagioclase, biotite, opaque minerals, hornblende, and clinopyroxene (fig. 2). The groundmass is microcrystalline with abundant small phenocrysts of plagioclase and opaque minerals. Biotite from a flow northeast of the Willow Creek Reservoir dam yielded a date of 37.23±0.1 Ma ($^{40}Ar/^{39}Ar$; table 1). The total thickness, as exposed along Willow Creek Reservoir near the dam, is 160 m.

Tbc **Tuff of Big Cottonwood Canyon (late Eocene)** Reddish-brown to light-tan rhyolite tuff forms ridges near Willow and lower Ivanhoe Creeks. The tuff is massive, very strongly welded, and featureless, and it forms a very planar dip slope on the ridges. Phenocrysts include plagioclase, quartz, sanidine, and biotite (fig. 2). The groundmass is composed of eutaxitic ash that is visible only in thin section. The contact with the underlying tuff of Nelson Creek (Tnc) is poorly exposed. Composition: 75% SiO_2, Na_2O+K_2O=8.4%. Sanidine from the tuff produced a $^{40}Ar/^{39}Ar$ date of 39.22±0.1 Ma (table 1). The tuff was erupted from the Big Cottonwood Canyon caldera in the Tuscarora Mountains to the northeast (Henry and Boden, 1998). The unit here is renamed from the tuff of Willow Creek Reservoir of Wallace and John (1998). The unit is about 150 m thick.

Tnc **Tuff of Nelson Creek (Eocene)** Light-tan, weakly welded tuff forms a single cooling unit with possibly two eruptive units beneath the tuff of Big Cottonwood Canyon. The tuff compositionally is a rhyolite to trachydacite (65-75% SiO_2, Na_2O+K_2O=7.5-8.1%). The tuff contains abundant lithic fragments, including large (30 cm) pumice blocks near the top of the unit. Phenocrysts are abundant and include plagioclase, biotite, quartz, sanidine, and altered hornblende (fig. 2). The groundmass is composed of ash and small fiamme. The unit is correlated, on the basis of phenocryst assemblage and stratigraphic position, with a 39.42±0.11 Ma ash-flow tuff unit exposed along Nelson Creek in the western Tuscarora Mountains (Henry and others, 1999; table 1). The unit previously was considered to be the lower part of the tuff of Willow Creek Reservoir (Wallace and John, 1998). The contact with the underlying Vinini Formation (Ov) in the northwestern part of the quadrangle is a poorly exposed red soil horizon, 1- to 3-m-thick with locally abundant angular fragments of quartzite, that represents an Eocene paleosol developed on the Vinini ("Fragmental Unit", in part, of Bartlett and others, 1991). The tuff is at least 150 m thick.

Ov **Vinini Formation (Ordovician)** Quartzite and chert with subordinate argillaceous sedimentary rocks are exposed along and west of Ivanhoe Creek, in sec. 28 along north side of Willow Creek, and in the southeastern corner of quadrangle. Minor basalt also was reported (Bartlett and others, 1991) but was not seen in this study. Quartzite is bluish white to tan, weathers to a dark-brown color, and forms locally prominent outcrops. Quartzite is composed of well-sorted quartz grains, and cross bedding locally is visible. It contains thin interbeds of pebble conglomerate, with subrounded quartzite and dark chert pebbles, as well as discontinuous zones of lithified intraformational breccia with angular fragments of quartzite. Chert is dark brown, and outcrops are massive to strongly bedded. Argillite does not crop out but forms locally abundant tan float of small, platy chips and larger material. Drilling data (Bartlett and others, 1991) indicate the Vinini is present at variable depths beneath the Tertiary volcanic rocks throughout the quadrangle. The unit was named Valmy Formation by Bartlett and others (1991). It is designated here as Vinini to be consistent with mapping, extensive well-exposed sequences, and paleontological data in the adjacent Santa Renia Fields Quadrangle to the southeast (fig. 1; Theodore and others, 1998; see discussion in accompanying text).

See accompanying text for figures, tables, discussion of stratigraphic and structural framework of the quadrangle, and references cited.



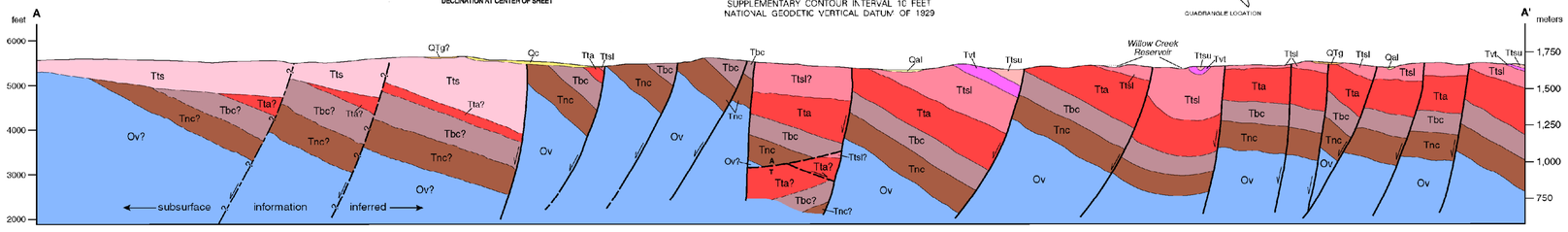
Topographic base from U.S. Geological Survey, Willow Creek Reservoir Quadrangle, 1965. Polyconic projection. 1927 North American datum.

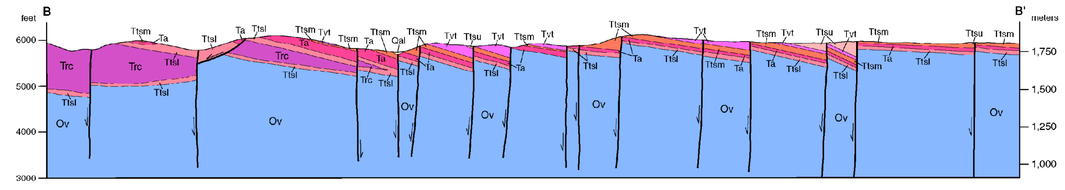
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
SUPPLEMENTARY CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION





Contact Rarely exposed and thus mapped approximately. Dashed where very approximately located due to poor exposures; dotted where concealed. Dotted contacts between undivided tuffaceous sedimentary rocks (Tts) and divided tuffaceous sedimentary rocks (Ttsu, Ttsm, Ttsl) based on limit of definitive exposures of divided units.

Fault Rarely exposed and thus mapped approximately, especially in tuffaceous rocks. Dashed where very approximately located or inferred; dotted where concealed by younger deposits. Bar and ball are on downthrown block. Arrows on map shows dip direction of fault. A, T: movement away and toward plane of view in cross section. Arrows on cross section show relative movement of fault. Dips on faulted sedimentary and volcanic units suggest that some or many faults may have shallower dips than shown on cross sections, but approximate surface traces of most faults indicate steep dip on faults.

Lineament Visible on aerial photographs but of uncertain origin.

Syncline Showing plunge of fold axis. Shown in Miocene rocks north of Willow Creek Reservoir.

Antiform Shown in Vinini Formation (Ov) along Ivanhoe Creek.

Dike Narrow feeder dikes for rhyolite porphyry (Trp).

Strike and dip of bedding

20 Inclined ⊕ Horizontal

Strike and dip of joints Shown in Ordovician rocks in southeastern part of quadrangle.

55 Inclined

Sample location for $^{40}Ar/^{39}Ar$ date analysis

■ 15.10±0.06

Areas of silicified rocks Massive chalcedony and opaline silica preferentially and completely replaced tuffaceous units and rhyolite flows. Strong to moderate replacement silica is ubiquitous in the middle tuff unit (Ttsm) throughout the southwestern part of the quadrangle, and those silicified areas are not shown separately on the map. Secondary silica also is present in the andesite and vitric tuff in the southwestern part of the quadrangle, and in the upper tuff unit east of Ivanhoe Creek. Silicified zones are predominantly white, but locally also light gray to pinkish to black; silicified rocks in these zones are glassy, with opaline luster, and hard and extremely brittle. They contain abundant angular, light-gray, chalcedonic fragments in a white chalcedonic to opaline groundmass. Within some silicified zones, massive chalcedony grades into silicified but recognizable tuffaceous rock; elsewhere, the silicification "front" is very sharp. The secondary silica zones contain abundant cinnabar in and around mines and many prospects. Silicification in the quadrangle took place between about 15.2 Ma and at least 14.92±0.05 Ma, but it was of shorter duration in any one place (Wallace, 2003b).

Field work conducted from 1996-98 by A.R. Wallace.

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