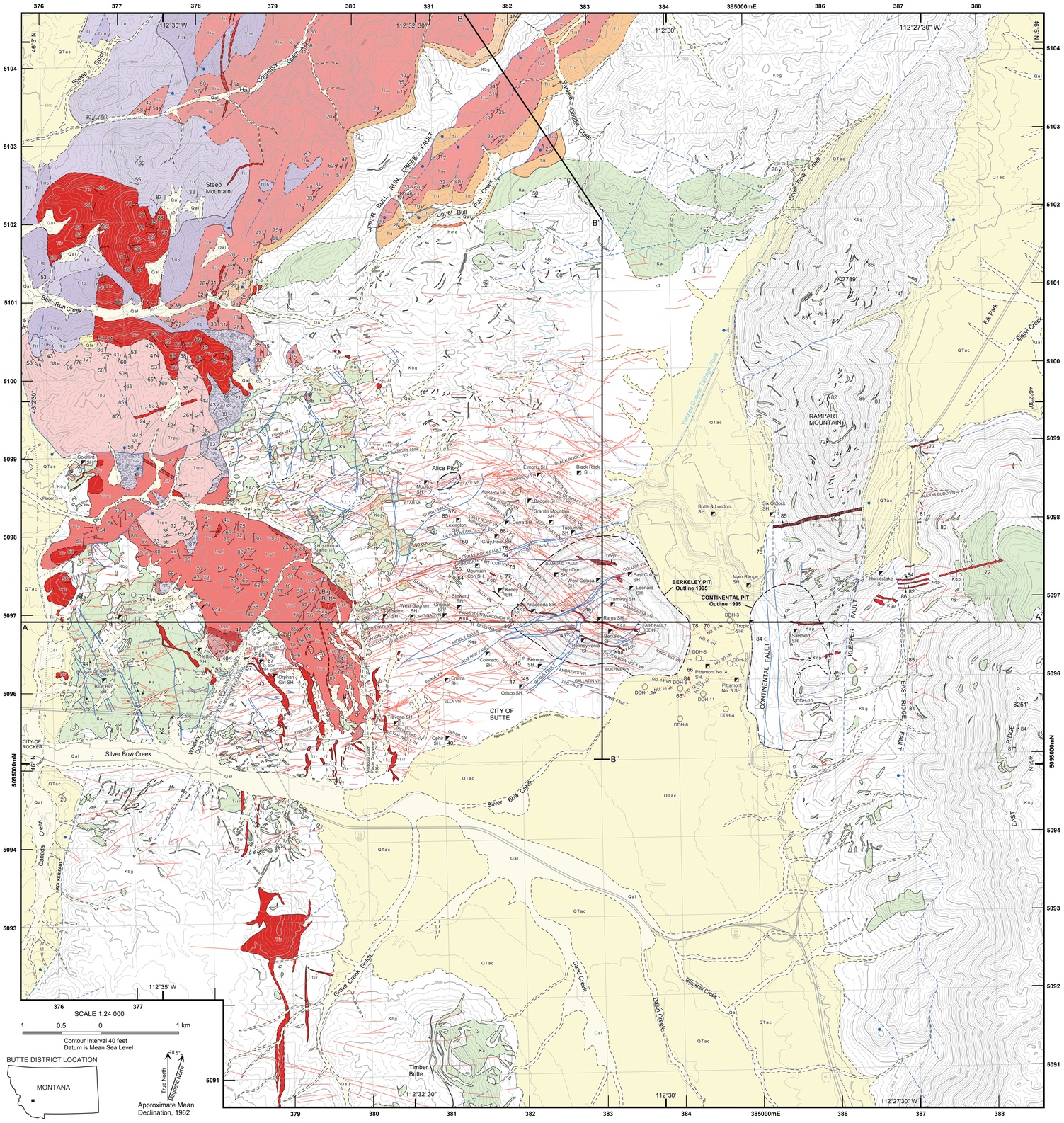
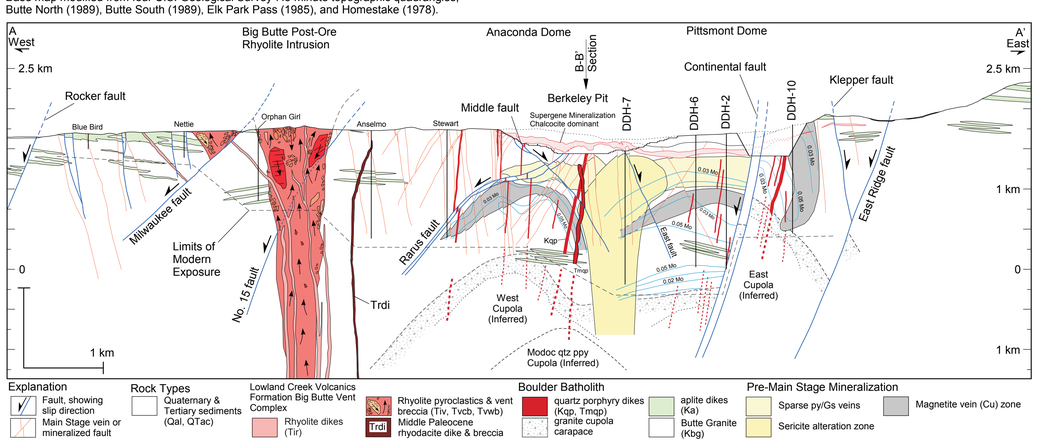
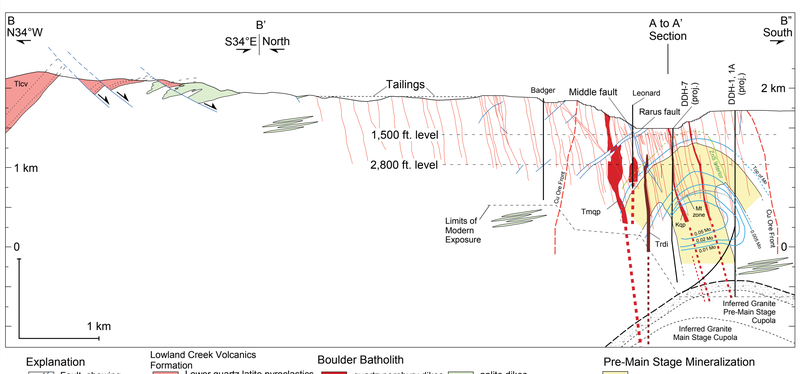
GEOLOGY OF THE BUTTE MINING DISTRICT, MONTANA



Base map modified from four U.S. Geological Survey 7.5 minute topographic quadrangles; Butte North (1989), Butte South (1989), Elk Park Pass (1985), and Homestake (1978).





Explanation
- Fault, showing slip direction
- Main Stage vein or mineralized fault

Rock Types
- Quaternary & Tertiary sediments (Qal, QTac)

Lowland Creek Volcanics Formation Big Butte Vent Complex
- Rhyolite dikes (Tir)
- Rhyolite pyroclastics & vent breccia (Tiv, Tvcb, Tvwb)
- Trdi Middle Paleocene rhyodacite dike & breccia

Boulder Batholith
- quartz porphyry dikes (Kqp, Tmqp)
- granite cupola carapace
- aplite dikes (Ka)
- Butte Granite (Kbg)

Pre-Main Stage Mineralization
- Sparse py/Gs veins
- Sericite alteration zone
- Magnetite vein (Cu) zone

Explanation
- Fault, showing slip direction
- Main Stage vein or mineralized fault

Lowland Creek Volcanics Formation
- Tlcv Lower quartz latite pyroclastics & sediments (Tlw, Tlat, Tlt)
- Trdi Middle Paleocene rhyodacite dike & breccia

Boulder Batholith
- quartz porphyry dikes (Kqp, Tmqp)
- granite cupola carapace
- aplite dikes (Ka)
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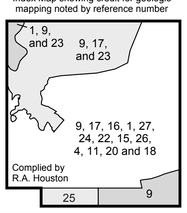
Pre-Main Stage Mineralization
- Sericite alteration zone
- Magnetite vein (Cu) zone

Index Map showing credit for geologic mapping noted by reference number



CORRELATION OF MAP AND CROSS SECTION UNITS

Units	Epoch	Period
Qal, Qls, QTac	Recent / Recent to Miocene	QUATERNARY
Tiv, Trpu, Trpl, Trpb$_c$, Trpb$_b$, Trpb$_a$, Tll, Tllb, Tlw, Tlat, Tlt	Eocene	TERTIARY
Trdi	Paleocene	TERTIARY
Tmqp, Kqp, Ka, Kme, Kbg	Late Cretaceous	CRETACEOUS

Main Stage Mineralization
Pre-Main Stage Mineralization

DESCRIPTION OF MAP UNITS

QUATERNARY and TERTIARY DEPOSITS

Qal **Recent Alluvium deposits** - Clay, silt, sand, and gravel fluvial detritus from eroded local granitic and volcanic rocks. Includes colluvium, lacustrine and terrace deposits.

Qls **Landslide deposits** - Poorly sorted material derived from bedrock and surficial deposits primarily occur as slump blocks and incipient rotational slumps.

QTac **Older Alluvium and colluvium deposits** - Poorly sorted, unconsolidated to moderately indurated, well-rounded, arkosic silt, sand, pebble and cobble detritus locally derived from granitic and volcanic rocks. Basin fill sediments near the town of Rocker are approximately 180 to 300 m thick (Feiveson, 1997; Hammar-Klose, 1997). Recent to Miocene sedimentary rocks contain locally air-fall rhyolite tuffs. Rare fossil camel, rhinoceros, horse, and oreodont teeth and bones are present in deposits south of Silver Bow Creek (Smedes et al., 1973). Locally, includes talus deposits comprised of unsorted cobble to boulder angular rock fragments and debris flow deposits adjacent to the Rocker, Continental, Klepper, and East Ridge faults, and Recent valley fill and alluvial terrace deposits (Pleistocene and Pliocene age; Elliott and McDonald, 2009).

TERTIARY VOLCANIC ROCKS

Lowland Creek Volcanics Formation - Modified from Smedes, (1962)

Big Butte Vent Complex

Tiv **Rhyolite dikes** - Light gray to red-brown, porphyritic rhyolite dikes and shallow irregular intrusive bodies contain plagioclase, quartz, and biotite phenocrysts surrounded in an aphanitic groundmass. Dikes south of Big Butte contain lineated flow foliation and chilled margins parallel to intrusive contacts. North of Bull Run Creek a large rhyolite intrudes dacite lavas and may be the base of an extrusive dome.

Trpu **Upper rhyolite pyroclastics** - Light gray to reddish, moderately to strongly welded rhyolite pyroclastic rocks (ignimbrite) contain 25 to 35 volume percent crystals of shattered crystals of quartz, oligoclase-andesine, biotite, and minor sanidine in a vitroclastic matrix. Abundant fiammé have an aspect ratio of approximately 6H:1V and are circular in plan view, suggesting simple compaction. The upper rhyolite pyroclastic rocks are petrographically similar to the lower rhyolite pyroclastic rocks (Trpl), but are locally overlying Trpl along a lithic-rich basal vitrophyre, up to 5 m thick. In the north west part of the district, the occurrence of several vitrophyres, up to 5 m thick, suggests multiple cooling units.

Trpb$_c$, Trpb$_b$, Trpb$_a$ **Pyroclastic breccia** - Includes three subunits consisting of angular blocks (<1 m to 30 m in diameter) of granite, aplite, quartz latite ignimbrite, dacite lava, and welded rhyolite tuff surrounded in a poorly welded matrix pyroclastic rhyolite. The matrix contains broken crystal fragments of quartz, plagioclase, sanidine, and biotite. Pyroclastic breccia (<200 m wide) locally occurs at the contact of the lower rhyolite pyroclastic (Trpl) and granite (Kbg). Three subunits are subdivided based on dominant clast lithology. Trpb$_a$, dominated by granite and aplite clasts. Trpb$_b$, dominated by quartz latite ignimbrite blocks that locally contain distinctive eutaxitic foliation. Trpb$_c$, dominated by dacite lava and breccia clasts that contain planar flow aligned plagioclase phenocrysts surrounded in an aphanitic groundmass. The pyroclastic breccia may represent the collapse of previously erupted surface rocks into the vent.

Trpl **Lower rhyolite pyroclastics** - Light gray to reddish-brown, moderately to strongly welded rhyolite pyroclastic rocks (ignimbrite) contain 25 to 35 volume percent crystals of shattered oligoclase-andesine, quartz, biotite and sanidine in a vitroclastic matrix. The ignimbrite is intercalated locally with thin (<10 m thick) breccia lenses. Abundant (up to 20 vol. %.) cognate clasts of rhyolite and lesser amounts of partially flattened fiammé (2H:1V to 1.5V aspect ratio) are oriented parallel to the near vertical fabric. This steeply dipping foliation becomes highly contorted, locally. The rhyolite pyroclastic rocks at Big Butte have a $^{40}Ar/^{39}Ar$ age of 52.9 ± 0.14 Ma (Dudás et al., 2010).

Extrusive

Tll **Dacite lava** - Brown to purplish red dacite lava (<120 m) consisting of abundant flow-aligned plagioclase phenocrysts (20 vol. %), biotite-rich glomerocrysts, orthopyroxene, hornblende, quartz and trace amounts of apatite and opaques are surrounded in an aphanitic groundmass (70 vol. %). There is no age determination for these dacites at Butte, but Dudás et al. (2010) suggest an age of 52.4 Ma based on a dacite sample southwest of Butte.

Tllb **Volcanic breccia** - Light-gray, brown to purplish red breccia consists of a lower matrix-supported part and an upper clast-supported part. The lower discontinuous part (up to 50 m thick) contains subangular (less than 1 m diameter) ash-flow tuff and dacite lava fragments (60 vol. %) supported by a light-brown to very pale orange devitrified ash matrix. This lower sequence may represent a volcanic debris flow or lahar. The upper part (up to 120 m thick) of the breccia unit is dominantly framework-supported angular porphyritic dacite lava boulders (90 vol. %) up to 2 m in diameter that are enclosed in a lavender-gray dacite lava matrix. The upper breccia sequence is an autobrecciated lava along the base of the overlying dacite lava (Tll).

Tlw **Quartz latite ash-flow tuff** - Light gray, reddish-brown and olive, poorly to strongly welded quartz latite ignimbrite contains shattered plagioclase, biotite, and hornblende crystals in a vitroclastic matrix. Eutaxitic textures are defined by conspicuous fiammé. Normal grading of lithic fragments occurs as repeated distinct zones upward in the section and correlates to 13 thin cooling units marked by distinct welding breaks. Locally, the ignimbrite is up to 300 m thick. In general, hornblende crystal abundance increases slightly from 1 to 5 vol. % upwards in the section. A vitrophyre up to 30 cm thick locally marks the basal contact. This ignimbrite has a $^{40}Ar/^{39}Ar$ age of 52.9 ± 0.14 Ma (Dudás et al., 2010)

Tlat **Rhyolitic air-fall tuff and base surge deposits** - Light gray, unwelded laminated and cross-bedded crystal-poor ash air-fall and base surge deposit (<50 m) with up to 15 vol. % lithic fragments. This upper unit is interpreted to be the base surge and airfall deposits precursor to the overlying quartz latite ignimbrite.

Tlt **Volcaniclastic sedimentary deposits** - Fluvial mudstone, siltstone, sandstone, and pebble conglomerate sedimentary sequences containing reworked volcaniclastic sedimentary rocks. Laminated micaceous mudstones and siltstones grade upward into coarse-grained and rippled arkosic and tuffaceous sandstones. Cross-bedding, ripples and petrified logs indicate a SSW-NNE bi-directional fluvial flow-direction. This sedimentary unit (<50 m) was deposited on an irregular erosional surface, locally marked by deeply weathered granite (grus) surrounding intensely weathered boulders of granite and aplite.

Intrusive

Trdi **Rhyodacite dike of Rampart Mountain** - Gray, porphyritic rock contains phenocrysts of plagioclase, quartz, and biotite and rare 2 cm orthoclase set in a fine-grained aplitic groundmass (Meyer et al., 1968). From east to west, this dike transects the district for >7 km at depth. Normal displacement along the Continental fault has exposed this dike on Rampart Mountain and further east in a I-15 roadcut. In the hanging wall of the Continental fault, at approximately the 2,000 foot level, a breccia at the apex of the dike, known as the Mountain View breccia, continues upward ~100 m, but is not exposed at surface (Meyer, et al., 1968). Available $^{40}Ar/^{39}Ar$ and $^{206}Pb/^{238}U$ monazite ages suggest emplacement at ~59 Ma (Dilles et al., 2004).

LATE CRETACEOUS PLUTONIC ROCKS

Boulder Batholith

Tmqp **Modoc quartz porphyry plug, irregular intrusions and breccia** - Light gray to grayish-green, porphyritic rock contains phenocrysts of plagioclase, rounded embayed quartz, sparse large (6 to 25 mm) K-feldspar, and biotite, in a very fine-grained groundmass of quartz and K-feldspar (64 Ma; Dilles et al., 2004). The Modoc quartz porphyry forms an irregular shaped plug that reaches a maximum width of ~300 m on the 2800 foot level of the Leonard mine (Meyer et al., 1968). Contacts are sinuous with moderate fragmentation of the granite (Meyer et al., 1968). Breccia fragments contain older quartz-molybdenite veinlets characteristic of the deep porphyry Cu-Mo zone.

Kqp **Quartz porphyry dikes** - Light colored, porphyritic rock (3 to 20 m wide) contains ca. 50 vol. % aplitic groundmass and 50 vol. % phenocrysts of euhedral plagioclase, rounded quartz eyes, orthoclase and biotite phenocrysts enclosed in a fine-grained groundmass of quartz and orthoclase (66 Ma; Lund et al., 2002).

Ka **Aplite, granoaplite, and pegmatite dikes and irregular intrusions** - Light colored to pink dikes consisting of orthoclase, quartz, oligoclase-andesine and trace amounts of biotite, contain local occurrences of pyrite, chalcopyrite, magnetite, albitic plagioclase and very rare pyrrhotite in quartz in the core zones (Meyer et al., 1968; Smedes et al., 1962). Black tourmaline and molybdenite also occur in miarolitic cavities and are most abundant in the deepest plutonic exposures along East Ridge. Granoaplite dikes (described as a granite-aplite hybrid rock; Roberts, 1975) contain phenocrysts of plagioclase, biotite, hornblende and rounded quartz eyes entrained in fine-grained aplitic quartz and alkali feldspar groundmass (76 Ma; Lund et al., 2002). Most dikes are gently-dipping and make up parallel sheeted sets. Aplite dikes are cm- to m-thick and typically have sharp contacts with the granite. Aplite dikes locally exceed 20 m thickness and commonly zone inward to pegmatitic cores (Meyer et al., 1968). Most granoaplite dikes occur as massive gently dipping planar sheets that exceed 20 m in thickness. Contacts are gradational with the granite. Sheeted aplite dikes are abundant in the western and eastern parts of the Butte district and intrude parallel to subhorizontal joint sets observed throughout the Butte district.

Kme **Mafic enclaves** - Dark-green to black ellipsoidal nodules (15 to 50 cm dia.) containing crystals of plagioclase, hornblende, biotite, quartz, magnetite and minor apatite. South and adjacent to Bull Run Creek, abundant nodules occur in a linear collection (~15 by 400 meters). At this location nodules are surrounded by fine-grained granite (Kbg). Elsewhere, isolated nodules occur throughout the district. Enclaves cut by aplite dikes.

Kbg **Butte Granite** - Gray, medium- to coarse-grained equigranular rock consists of plagioclase (35-40 vol. %), orthoclase (20-25 vol. %), quartz (15-25 vol. %), and about 20 vol. % biotite, hornblende, magnetite, titanite, ilmenite, and apatite (76.5 Ma; Meyer et al., 1968; Martin et al., 1999; Martin and Dilles, 2000, Lund et al., 2002). The granite has distinctive euhedral poikilitic K-feldspar megacrysts up to 3 cm in length (Smedes et al., 1962; Meyer et al., 1968). Occasional mafic enclaves and aplite dikes are present throughout the granite (Houston, 2001).

- 85 — **Contact** - showing dip; dashed where approximately located; and dotted where concealed
- 78 D U — **Fault** - showing dip; dashed where approximately located; dotted where concealed; Names shown on principal faults
- 64 D U — **Vein or mineralized fault** - showing dip; dotted where concealed; Names shown on principal veins
- 25 — **Strike and dip of beds** - shown in all bedded units including sedimentary rocks and sedimentary interbeds within lava flows
- 15 — **Strike and dip of compaction foliation structure**
- 10 — **Strike and dip of rheomorphic foliation**
- 75 — **Strike and dip of joint**
- **Bidirectional paleoflow indicator**
- DDH-8 — **Anaconda/ARCO Deep Drill Hole Locality**
- **Productive Mine Shaft**
- **Open-pit outline**: Berkeley Pit and Continental Pit
- **Waste rock** **Tailings pond** **Historic landfill**

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GEOLOGY OF THE BUTTE MINING DISTRICT, MONTANA

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2013

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