GEOLOGIC MAP OF THE CENTENNIAL WASH QUADRANGLE MOHAVE AND LA PAZ COUNTIES, ARIZONA

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INTRODUCTION

The Centennial Wash quadrangle is important for understanding the tectonic framework of west-central Arizona because it includes the north boundary of the Rawhide Mountains. These mountains are part of one of the most extensive metamorphic core complexes (as defined by Coney, 1980) in the Cordillera. The quadrangle includes the three tectonic elements that characterize metamorphic core complexes: upper plate, lower plate, and the detachment fault separating the two. In this area, the fault is known as the Rawhide detachment fault.

This quadrangle is one of several that have been mapped along a northeast-trending belt of nearly continuous exposures extending from the Buckskin-Rawhide metamorphic core complex to the Colorado Plateau near Wikieup, Arizona (figs. 1, 2) (Lucchitta and Suneson, 1988a, b, 1990, and in press a, b, c; Lucchitta and Beard, unpub. mapping, 1980–84). These maps explore the structural transition from the highly extended terrane of the metamorphic core complexes to the relatively stable Colorado Plateau.

STRATIGRAPHY

The lower plate is exposed in the southern part of the quadrangle, near the margin of the Buckskin-Rawhide metamorphic core complex (fig. 3). The lower plate is composed of foliated gneissic rocks that are characterized by a well-developed lineation plunging approximately southwest in the plane of the foliation (Shackelford, 1989). The dominant lithology is mylonitic quartz-feldspar gneiss whose protolith is probably mostly Proterozoic plutonic rocks. Mesozoic(?) and Tertiary(?) plutonic rocks, now indistinguishable from the Proterozoic rocks, may also be present within the gneiss complex. Irregular bodies of metasedimentary rocks within the mylonitic quartz-feldspar gneiss are less common. These rocks are predominantly calc-silicate rocks and quartzite whose protoliths may be Paleozoic (Shackelford, 1980).

The upper plate differs markedly from the lower plate in composition, degree of metamorphism, and structural style. Whereas the lower plate underwent severe ductile extension as late as the Miocene, resulting in the mylonitic quartz-feldspar gneiss, the upper plate underwent extreme brittle extension. This gave rise to the moderately dipping normal faults separating rotated blocks that are characteristic of the upper plate. Five suites of rocks are exposed in, but not restricted to, the upper plate: (1) Early Proterozoic(?), Middle Proterozoic, and Upper Cretaceous basement rocks; (2) Mesozoic(?) greenschist-facies metasedimentary and metavolcanic rocks; (3) upper Oligocene to middle Miocene syntectonic sedimentary and volcanic rocks; (4) upper Miocene basin-filling sedimentary and basaltic rocks; and (5) uppermost Miocene to Holocene sedimentary rocks and basaltic lava flows deposited on a topography that reflects through-flowing drainage of the Colorado River system.

The Early Proterozoic(?), Middle Proterozoic, and Upper Cretaceous basement rocks consist of orthogneiss, paragneiss, and several kinds of plutonic rocks, including the coarsely porphyritic Signal Granite named by Lucchitta and Suneson (1982), and Upper Cretaceous diorite and gabbro. Most of these rocks lithologically resemble the basement rocks of the adjacent Colorado Plateau and transition zone. Though not present in the immediate vicinity of the detachment fault, they have been mapped in a continuous belt extending from about 4 km from the fault northeastward onto the Colorado Plateau with no major tectonic discontinuity (Lucchitta and Suneson, 1988a, b, 1990, and in press a, b, c; Lucchitta and Beard, unpub. mapping, 1980–84). The upper plate is attached to the North American craton and thus is best thought of as autochthonous; the lower plate must then be the active element (Lucchitta and Suneson, 1981).

The Mesozoic(?) metasedimentary and metavolcanic rocks are present in a belt a few kilometers wide immediately north of the Rawhide detachment fault but are absent farther north and northeast. In contrast, rocks of this type are widely exposed in southwest Arizona and adjacent California. Greenschist-facies metamorphic rocks are the most common rock types; the protoliths include rhyolitic or dacitic tuff, volcanic sandstone, basalt, shale, siltstone, sandstone, and conglomerate. Metamorphism occurred before deposition of the overlying uppermost Oligocene to middle Miocene syntectonic sedimentary rocks, which are not metamorphosed.

Except for the basal unit, the Tertiary syntectonic strata were deposited during uplift of the Buckskin-Rawhide metamorphic core complex, which accompanied movement on the Rawhide detachment fault. Sedimentary and volcanic strata were deposited in tectonic basins that no longer have topographic expression. These basins were part of a larger, irregular trough that formed on the north flank of the rising Buckskin-Rawhide metamorphic core complex. The deposits include conglomerate and breccia, medium- to fine-grained clastic strata, lacustrine rocks such as limestone and gypsum, basalt, and rhyolite. The basal deposit is an arkosic sandstone and conglomerate mostly derived locally as weathered regolith on granite, but also from the Proterozoic basement to the northeast, as shown by clast composition and coarsening grain size in that direction. This southwest-dipping paleoslope may reflect the southern flank of the ancient Mogollon Highlands, a high belt that rimmed the south and southwest sides of the Colorado Plateau before mid-Tertiary rifting. Drainage from the northeast was interrupted by uplift of the Buckskin-Rawhide metamorphic core complex, which resulted in locally ponded drainage and deposition of fine-grained sediment from about 26.5 Ma (40-Ar/39-Ar, Institute of Human Origins, University of California, Berkeley, written commun., 1990) to the Miocene (palynomorphs, R.F. Hevley, written commun., 1979).

The ponding was followed by the emplacement of a large volume of debris of southerly derivation. This debris includes gravity-glide sheets as much as several kilometers across and a widespread and distinctive breccia that is exposed for many tens of kilometers along strike. The breccia is monolithologic in any one outcrop, but overall consists of a variety of rock types that are identical to those in the gravity-glide sheets, including Mesozoic(?) metavolcanic and metasedimentary rocks, Paleozoic(?) limestone and quartzite, and Proterozoic(?) plutonic rocks. In the breccia and glide sheets, these rock types generally are found in inverse stratigraphic order.

The gravity-glide sheets are interbedded with an arkosic conglomerate that, in the southern part of the quadrangle, contains clasts derived mostly from the south. In the northern part of the quadrangle, the conglomerate contains clasts derived mostly from the north. This conglomerate is offset by the Rawhide detachment fault and its uppermost part interfingers with rhyolitic rocks that are 12 to 14 Ma. This evidence and the observation that the silicic volcanic rocks are rotated along listric faults that terminate at the Rawhide detachment fault indicate that the fault still active at that time.

The basin-fill sequence consists chiefly of locally derived fanglomerate and mesa-forming basalt. Fanglomerate beds range from monolithologic to those containing a wide variety of clast types; in most cases, the clasts can be traced to nearby bedrock outcrops of identical rock type. The mesa-forming mafic lavas typically form isolated, petrographically distinctive sequences of flows and are about 9 to 13 Ma. The fanglomerate and mafic flows of the basin-fill sequence are gently tilted and offset by high-angle normal faults that have hundreds of meters of structural relief. The relation of the clasts in the fanglomerate to local bedrock and map distribution of the mesa-forming basalts indicates the basin-fill sequence accumulated in basins under conditions of interior drainage. These basins, of classic basin and range type, are bordered by mountains and bounded by high-angle normal faults.

The youngest strata in the quadrangle consist of alluvium associated with major drainages, piedmont-slope deposits, and megacrystic-basalt lava flows. The alluvium and piedmont-slope deposits were emplaced on slopes that parallel present ones. The megacrystic-basalt flows are about 7 Ma, only slightly structurally deformed, and flowed down drainages that parallel modern washes; these basalts clearly postdate the establishment of through-flowing drainage. The basalt lavas are interbedded with fanglomerate identical to that in the basin-fill sequence, indicating that the upper part of the basin fill was deposited under conditions of through-flowing drainage. The oldest megacrystic basalt in the region crops out in the nearby Castaneda Hills quadrangle and is about 8.5 Ma. This basalt flowed oblique to present drainages, is offset by high-angle normal faults, and is about 100 m above the present washes. It probably was erupted at the time of transition from interior- to through-flowing drainage conditions.

STRUCTURE

Most structural elements in the Centennial Wash quadrangle are related to extreme extension associated with development and uplift of the Buckskin-Rawhide metamorphic core complex. Basin and range, high-angle normal faults that postdate the extreme extension are exposed in quadrangles to the north.

The structural features characteristic of the lower plate, the upper plate, and the Rawhide detachment fault differ markedly from each other. The principal large-scale, lower-plate feature is the Buckskin-Rawhide metamorphic core complex itself, which is an elongate, northeast-trending antiform. The map area includes only the northwest flank of the antiform. Several smaller amplitude antiforms and synforms trending toward the northwest are superposed on this flank, and coincide with, and probably control, upper-plate fault blocks. Mesoscopic structural features in the lower plate indicate extreme ductile extension in a northeast-southwest direction and include boudinage and moderately dipping, penetrative mylonitic foliation and northeast-trending lineation.

The characteristic structural feature of the upper plate is northwest-striking, northeast-side-down normal faults that terminate at the Rawhide detachment fault and have throws of typically less than 1,500 m but exceeding 3,000 m in some cases. Movement on these faults resulted in pronounced rotation of the intervening fault blocks, which now dip southwest. Also present in the upper plate in the northeast part of the quadrangle are moderately to steeply dipping foliated mylonitic basement rocks (gneiss of Centennial Wash) with weak lineation that trends northwest. These rocks grade upward into nonmylonitic Middle Proterozoic Signal Granite and are intruded by the 90-Ma (table 2) weakly mylonitic to nonmylonitic diorite and gabbro (unit **dg**), which are late-kinematic to postkinematic. This shows that the mylonitization took place in the Late Cretaceous. The mylonite of Centennial Wash and associated basement rocks are overlain stratigraphically by the Tertiary syntectonic sedimentary sequence, whose basal units dip as much as 70°. Prerotation foliation in the gneiss of Centennial Wash (unit **gnc**) typically strikes about northwest and dips moderately to steeply northeast; the lineation typically trends northwest to north, in contrast to that of the lower-plate gneiss (**mgn**), whose lineation characteristically trends northeast to north.

The Rawhide detachment fault is subhorizontal regionally, but undulates in detail (fig. 3). The fault separates the lower and upper plates and is marked by a chlorite microbreccia and silicification.

In contrast to nearby quadrangles, no high-angle normal faults that are unequivocally related to basin and range deformation are exposed in the Centennial Wash quadrangle. A few high-angle faults, both normal and reverse, offset the Rawhide detachment fault and are therefore younger than the fault. These faults, which strike north to northwest, parallel upper-plate faults and later basin-range faults and are not associated with sediment-filled basins.

TECTONIC HISTORY

PRE-CENOZOIC

Evidence for pre-Cenozoic events is poorly preserved within this quadrangle in the lower plate of the Buckskin-Rawhide metamorphic core complex, because of overprinting by extreme ductile extension of Cenozoic age. Pre-Cenozoic events are better documented in the upper plate.

Basement rocks of the upper plate are part of the igneous and metamorphic terrane widely exposed along the west margin of the Colorado Plateau in west-central and northwest Arizona. This terrane consists of sedimentary, volcanic, and plutonic rocks that were affected by regional metamorphism in Early Proterozoic time. Metamorphism was followed by emplacement of the Signal Granite and equivalents in Middle Proterozoic time.

A Late Cretaceous metamorphic and plutonic event is documented in the Middle mountain area (fig. 3) by ductile deformation of pre-existing rocks, including the Signal Granite, and intrusion, near the end of this mylonitization event, of the 90-Ma diorite and gabbro. These features document a Late Cretaceous thermotectonic event that may also have produced the greenschist-facies metamorphism of Mesozoic (?) sedimentary and volcanic rocks (msv) of the upper plate. Tectonic transport during this event probably was in a northwest to north direction.

CENOZOIC

Cenozoic tectonic events of late Oligocene and younger age are well documented in the Centennial Wash quadrangle, particularly in the upper plate.

Cenozoic tectonism consisted of three partially overlapping events. The first was associated with uplift and extension of the Buckskin-Rawhide metamorphic core complex. Excepting perhaps the basal arkose, the oldest deposits (about 26 to 17 Ma) accumulated in a linear trough at the northern base of the mountains formed by the rising metamorphic core complex. Later (17 to 11 Ma) deposits accumulated in small, fault-bounded basins formed in the upper plate by movement on listric(?) or "planar domino"(?) normal faults. These faults rotated the intervening fault blocks to dip southwest, are relatively closely spaced, and have relatively small structural displacements. The faults formed as a result of extreme extension associated with formation of the Buckskin-Rawhide metamorphic core complex and accompanied by continued uplift of the complex. This extension also resulted in formation of the nearly horizontal Rawhide detachment fault by southwest displacement of the lower plate relative to the upper plate. The basins formed by the listric(?) faults no longer have topographic expression.

The second tectonic event (about 13 to 8 Ma) is represented by widely spaced, north-striking, high-angle normal faults with substantial structural relief and minor rotation. These faults are best documented north and northwest of the Centennial Wash (Planet 2 SE) quadrangle (Lucchitta and Suneson, 1988a, 1990, and in press a, b); in this quadrangle they may include high-angle faults that offset the Rawhide detachment fault. The faults of the second tectonic event are of classic basin and range type and formed the basins (grabens) and ranges (horsts) still visible today. During this event, basin-filling fanglomerate and mesa-forming basalt accumulated in the basins under conditions of interior drainage.

The third event (about 8 Ma to present) has consisted of tectonic quiescence, which has allowed the reestablishment of through-flowing drainage in the region. Thin veneers of piedmont-slope deposits, alluvial deposits, and megacrystic basalts that flowed down present drainages accumulated during this period.

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Table 1. *Radiometric-age determinations in the Centennial Wash quadrangle*

Map No.	Field No.	Map Unit	Age(Ma)	References
1	CH-26	Tbq	13.7±0.3	Suneson and Lucchitta, 1979
2	CHSE-164	Tmbc	13.0±0.5	--Do.--
3	CHSE-135A	Tmbh	11.3±0.7	Suneson and Lucchitta, 1983
4	CHSE-135B	Tmbh	12.0±1.7	Suneson, 1980
5	CHSE-166	Tbmx	7.7±0.5	Suneson and Lucchitta, 1979

Table 2. *Analytical data for 40-Ar/39-Ar age determinations on diorite and gabbro (unit* **dg***), radiometric-age sample 6*

[Analyses by Geochronology Laboratory, Institute of Human Origins, Berkeley, Calif. Bio, biotite; hbl, hornblende]

Sample No.	Mineral	Isotopes 37/39	Isotopes 36/39	Isotopes 40/39	Percent radiometric	Age(Ma)	Sandard deviation
3121-06	Bio	0.12806	0.016013	12.99576	73.3	83.451	0.334
3121-01	Bio	0.21486	0.014490	13.10714	75.4	84.150	0.330
3121-02	Bio	0.17331	0.019449	14.06807	71.0	90.168	0.427
3121-04	Bio	0.11997	0.021546	14.17937	69.0	90.863	0.438
3121-03	Bio	0.05429	0.010726	14.45714	82.0	92.598	0.464
3121-05	Bio	0.14549	0.021005	14.94170	70.7	95.621	0.540
3116-02	Hbl	18.72602	0.052333	28.62407	67.0	178.949	2.143
3116-05	Hbl	10.25379	0.016800	33.87123	89.1	209.911	1.463
3116-03	Hbl	10.68825	0.058337	64.48727	79.6	380.682	1.792
3116-01	Hbl	13.42085	0.059302	70.08940	80.9	410.253	2.276
3116-06	Hbl	37.38256	0.227528	75.41888	53.4	437.941	6.820
3116-04	Hbl	15.24565	0.067329	238.15760	92.7	1126.932	3.864

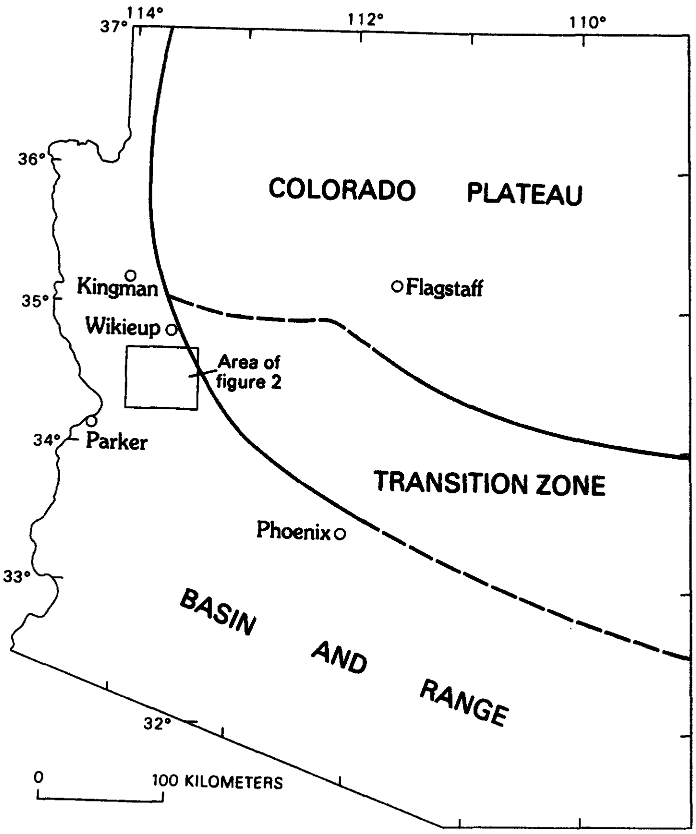


Figure 1. Map of Arizona showing major tectonic provinces (boundaries dashed where approximately located).

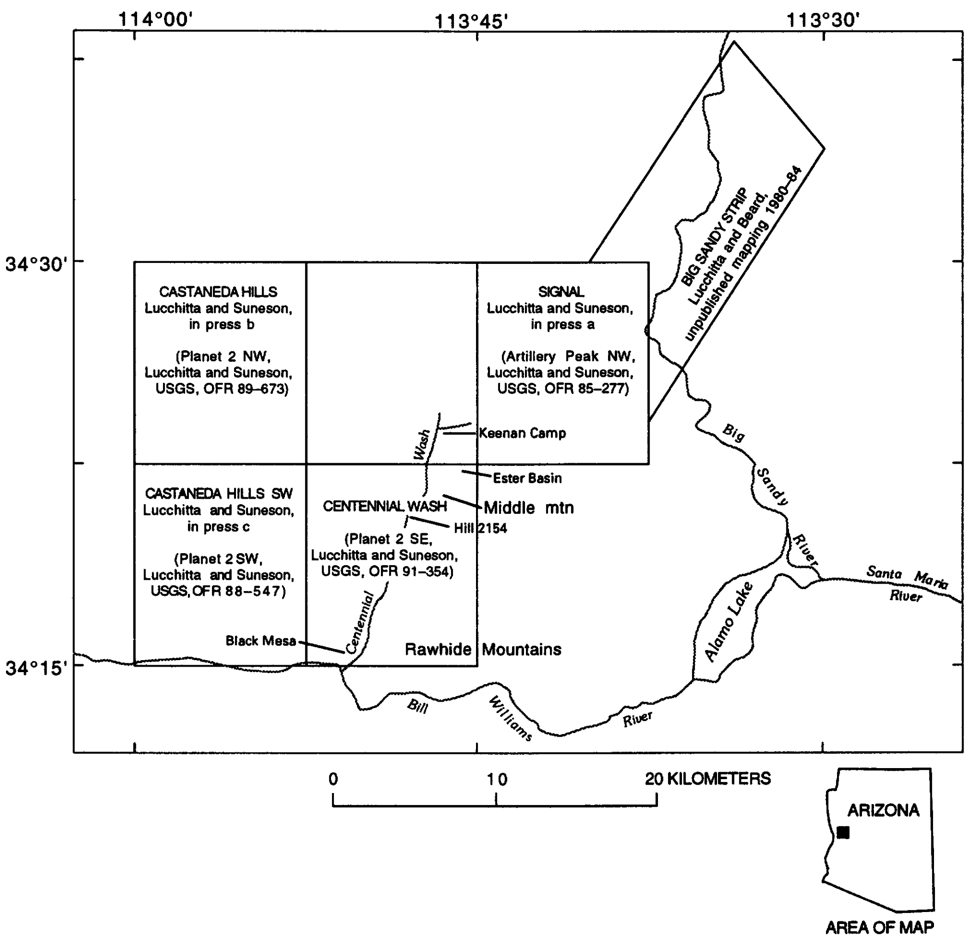
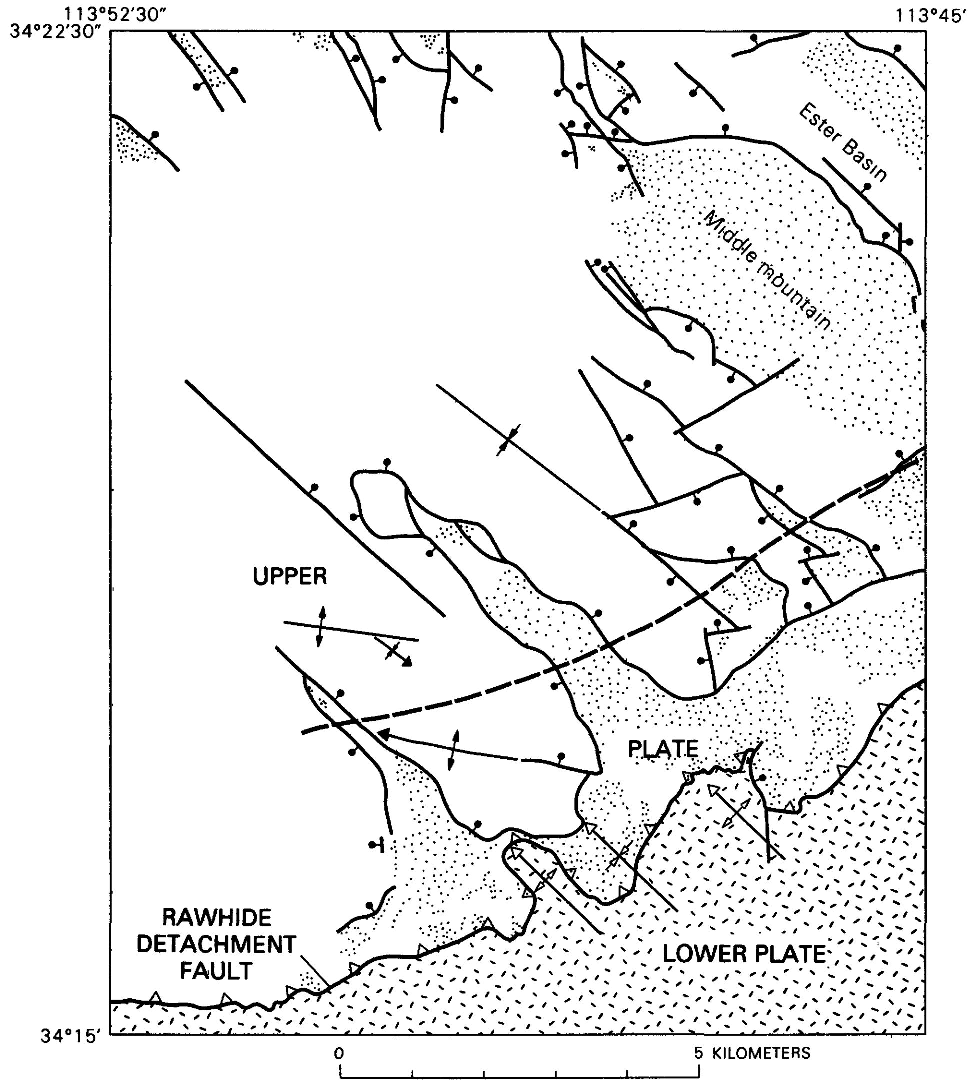


Figure 2. Mapped 7½' quadrangles relative to geographic features. Preliminary (old) quadrangle names and published U.S. Geological Survey Open-File Reports in parentheses.



EXPLANATION

Rawhide detachment fault

Normal fault—Bar and ball on downthrown side

Folds in upper plate rocks—Showing direction of plunge
- Anticline
- Syncline

Folds in lower plate rocks—Defined by warps in the Rawhide fault, showing direction of plunge
- Anticline
- Syncline

Areas of exposure of oldest rocks in upper plate—Includes map units msv, sch, gnc, gn, and Ys

Areas of exposure of metamorphic rocks of the lower plate—Including map units mms and mgn

Northern limit exposure of gravity-glide sheets

Figure 3. Map showing main structural features in Centennial Wash quadrangle.

*U.S. G.P.O.:1994-301-077:80105