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PETROGRAPHY AND PROVENANCE OF CAMBRO-ORDOVICIAN BLISS SANDSTONE, SOUTHERN NEW MEXICO AND WEST TEXAS

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Abstract—The Cambrian-Ordovician Bliss Formation consists of high-energy wave- and storm-generated deposits. Bliss sandstones are quite diverse but quartz arenites and subarkoses are the dominant lithic types. Arkoses are subordinant and preferentially occur near the base of the formation. Petrographic and modal analyses indicate that Bliss sandstones were derived from Precambrian and Cambrian granitic plutons, and metaigneous and metasedimentary rocks of southern New Mexico. Locally, detrital grains and deflected paleocurrent patterns indicate the presence of basement structural highs. The Bliss Formation is part of a miogeoclinal assemblage deposited on a passive continental margin. The Precambrian-lower Paleozoic succession of southern New Mexico and west Texas represents the transition from a rifted setting to an Atlantic-type margin. Bliss sandstones, however, do not consist of primary rift sediments, but largely of reworked cratonal detritus.

INTRODUCTION

Shallow seas covered much of the North American craton during the Late Cambrian and Early Ordovician. A major transgression and several minor regressions occurred in the southwestern United States during this time (Flower, 1965). The Bliss Formation is a good example of a clastic epeiric sea deposit common in the Cambro-Ordovician. Lithofacies of the Bliss are varied in the study area (Fig. 1) and have been interpreted as wave- and storm-dominated deposits (Stagemen, 1987). Eight facies were identified (Stageman, 1987): (1) trough crossbedded sandstones, (2) planar crossbedded sandstones, (3) coarse lags overlain by horizontally laminated sandstones, (4) wave-rippled sandstones, (5) hummocky cross-stratified sandstones, (6) horizontally laminated sandstones, siltstones and shales, (7) limestones and dolomites and (8) massive sandstones. Bliss lithologies are varied as well, but are dominantly sandstones. Arkoses are commonly present in the basal part of the formation, but quartz arenites and subarkoses are the dominant rock types throughout the formation. The Bliss Formation is conformably overlain by carbonates of the El Paso Formation and unconformably overlies Precambrian and Cambrian granitic plutons, metaigneous, metasedimentary and sedimentary rocks of southern New Mexico and west Texas.

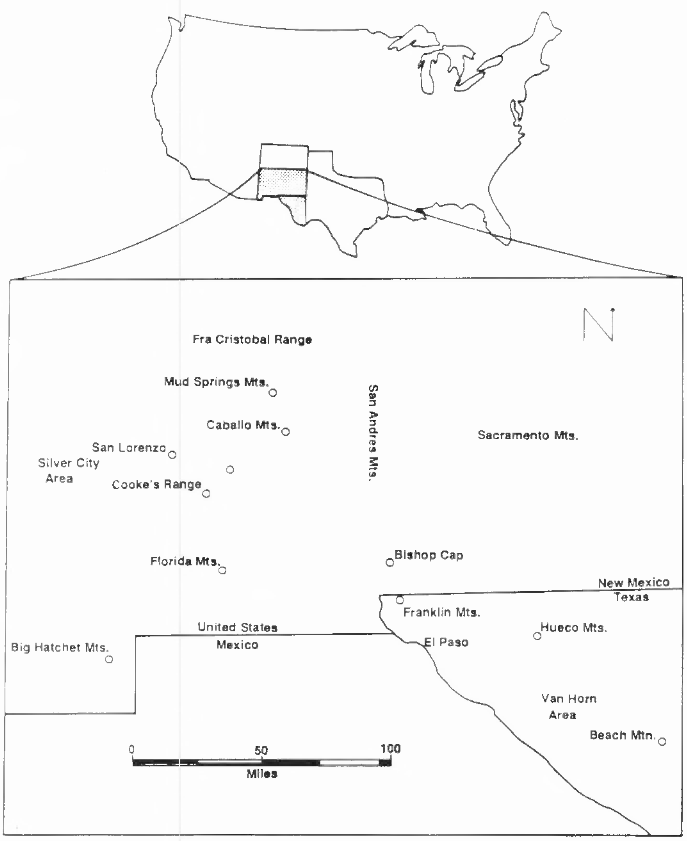

FIGURE 1. Index map of the study area showing sample locations (circles). Specific sample locations are given in Hayes (1975) and Stageman (1987).

PRECAMBRIAN TERRANE

Three Precambrian crustal provinces are exposed in the cores of mountain ranges in southern New Mexico and west Texas (Condie and Budding, 1979). The provinces underlying the Bliss Formation in the study area (Fig. 1) are compositionally diverse, structurally complex and range from sublitharenite in Van Horn, Texas, to syenite in the Florida Mountains, New Mexico. Granitic plutons make up 70% of the terrane and are intruded into metamorphic rocks which make up 30% (Condie and Budding, 1979). Granitic rocks are dominantly quartz monzonites but range from granodiorite to syenite (Beers, 1976). The main metamorphic rock types are, in order of decreasing abundance: phyllite, quartz-mica schist, quartzite, arkosite, mafic metaigneous rocks, siliceous metaigneous rocks and gneisses (Condie and Budding, 1979).

METHODS

Detailed measured sections were completed with the aid of a Jacob staff and brunton compass. Ten Bliss sections were visited: Beach Mountain near Van Horn, Texas, Hueco Mountains, Hitt Canyon in the Franklin Mountains, Cable Canyon in the Caballo Mountains, Mud Mountain, San Lorenzo, two sections at Capitol Dome in the Florida Mountains, Salado Mountains and Mescal Canyon in the Big Hatchet Mountains (Fig. 1).

A total of 54 Bliss sandstones were point-counted at 300 grains for each detrital mode determination (Table 1). Interpretation of source rocks is based on a comparison of detrital modes of Bliss sandstones with detrital modes of Holocene sands of known crystalline source rocks (G. H. Mack, oral commun. 1985). Standard point-counting methods were employed in this study and do not follow those of Dickinson and Suczek (1979). Quartzo-feldspathic rock fragments are not recognized on their QFL diagram, therefore QFF data were divided into equal amounts of quartz and feldspar before plotting on triangular diagrams.

PROVENANCE

A variety of detrital grain types were noted in Bliss sandstones. Grain types observed, in order of decreasing abundance, were monocrystalline quartz (MXQ), sodic and potassic feldspar (PLG and KSP, respectively), polycrystalline quartz (PXQ), quartzo-feldspathic rock fragments (QFF), metamorphic rock fragments (MRF), sedimentary rock

TABLE 1. Detrital modes of the Bliss Formation. MXQ = monocrystalline quartz; PXQ = polycrystalline quartz; KSP = potassium feldspar; PLG = plagioclase feldspar; CHT = chert; PRF = pelitic rock fragment; MRF = metamorphic rock fragment; VRF = volcanic rock fragment; QFF = quartzo-feldspathic rock fragment; ACC = accessories.

Sample #	m above base	MXQ	PXQ KSP	PLG	CHT	PRF	MRF	VRF	QFF	ACC
Beach Mtn.										
BM-1.5	0		65.0	25.3	6.2			0.3	3.0	
BM-2	3.0	70.0	8.3	8.6				0.3	2.6	
BM-4	9.0	83.0	8.3	7.0				0.6	1.0	
BM-7	25.0	87.3	10.3	1.6					0.6	
BM-8	28.5	93.3	1.3	4.0					1.3	
BM-13	43.5	86.3	5.3	7.3	1.6				1.0	
Hueco Mtns.										
HM-1	0	70.0	1.6	7.6					20.6	
HM-3	19.5	96.0	2.5						1.5	
HM-5	42.0	93.3	3.3	1.3					2.0	
HM-7	64.5	98.3	1.0	0.6						
HM-8	75.0	96.6	0.6	2.6						
HM-11	82.5	86.8		13.2						
Hitt Canyon										
HC-1	0	49.0		34.6				0.6	15.6	
HC-3	9.0	93.0	1.3	3.6				0.3	1.0	
HC-5	22.5	90.0	2.3	6.2				0.3	1.0	
HC-6	33.0	82.6	2.0	12.6					2.6	
HC-7	49.5	71.6	0.3	25.9					2.0	
HC-9	64.5	67.6	1.0	30.2					0.6	0.3
Cable Canyon										
CC-1	0	60.6	3.6	18.0					17.6	
CC-2	6.0	75.7		14.2					8.5	1.4
CC-3	12.0	76.3	0.3	14.3					7.9	1.0
CC-6	27.0	69.3	0.3	23.6					5.0	1.6
CC-7	30.0	71.6		24.9					3.0	0.4
CC-8	33.0	74.6	20.3						4.3	0.6
Mud Mtn.										
MS-1	0	61.3	2.0	22.0					14.6	
MS-3	9.0	98.0	2.0							
MS-5	16.5	96.6		3.3						
MS-6	21.0	93.0	5.0	1.3		0.6				
MS-8	34.5	76.9		23.0						
MS-9	38.0	68.0	0.3	30.6						1.0
San Lorenzo										
SL-6	0	98.0	2.0							
SL-7	7.5	99.0	1.0							
SL-8	15.1	98.3	1.0							0.6
SL-9	22.5	98.6	1.0							0.3
SL-10	30.0	98.6	1.0				0.3			
SL-11	37.6	86.4	9.2		0.8	2.8	0.8			
NW Capitol Doma										
83-RC-25	0	57.6	7.3	22.6					12.3	
83-RC-26	2.2	42.3	55.6	2.0						
83-RC-27	6.1	63.3	2.6	27.6					6.3	
83-RC-33	14.6	63.0		37.0						
83-RC-35	17.7	67.3	1.0	31.6						
83-RC-38	30.8	89.0	0.3	10.6						
WSW Capitol Doma										
80-RC-120	0	46.0	12.0	33.6					8.20	
80-RC-123	8.23	49.3	6.3	36.9					7.3	
80-RC-126	17.4	48.6	7.6	33.6					9.9	
80-RC-130	36.0	58.6	12.3	16.6					12.3	
80-RC-132	45.12	73.6	12.6	10.6					3.0	
80-RC-133	48.8	64.6	1.0	30.3					3.9	
Mescal Canyon										
MC-1	0	77.0	6.3	7.3					9.3	
MC-2	9.0	53.6	1.3	23.6					21.3	
MC-3	18.0	92.6		5.6					1.7	
MC-4	27.0	98.6	1.3							
MC-5	34.5	98.0		2.0						
MC-6	37.5	96.0								4.0

fragments (PRF), volcanic rock fragments (VRF), and chert (CHT). Detrital grain types are shown in Figure 2.

Quartz is by far the most abundant detrital grain type in Bliss sandstones. Monocrystalline quartz is commonly undulose and has only one crystal unit per gain. Monocrystalline quartz commonly contains microlites but inclusions are too small to be identified with a standard petrographic microscope. Polycrystalline quartz (more than two crystal units per grain) also displays undulose extinction, deformation lamellae, elongated crystal units, sutured crystal-crystal boundaries, and several grains of undulose MXQ and PXQ display biaxial interference figures with an extremely small optic angle.

Detrital feldspars consist mainly of potassic varieties although plagioclase was also observed. Potassium feldspars were distinguished by staining with sodium cobaltinitrite. Microcline, orthoclase and perthite were observed. Ratios of KSP to PLG are extremely high. Plagioclase grains suitable for analysis using the method of Michel-Levy yielded compositions of An_{13}–An_{36}. The feldspars are commonly sericitized. Alteration to kaolinite and carbonate is locally important.

Lithic fragments present in the Bliss Formation include, in decreasing order of abundance, QFF, VRF, MRF and PRF. Quartzo-feldspathic rock fragments are interpreted to be granitic rock fragments because they are subangular to angular lithic grains consisting of quartz and feldspar. Volcanic rock fragments are important in the Franklin Mountains and are rhyolite fragments. Metamorphic rock fragments display excellent foliation and range from quartz-mica schist to meta-diabase. Sedimentary rock fragments are not abundant but consist of siltstone and sandstone clasts, and reworked detrital quartz. Detrital chert is very rare.

Source rocks

The abundance of MXQ, KSP and QFF indicates a dominantly granitic source. Metamorphic rock fragments and PXQ indicate that the Bliss was derived, in part, from metamorphic rocks or reworked sediments. In the absence of MRF, textures of PXQ also indicate a metamorphic source. Undulosity, deformation lamellae, crystal elongation and primary recrystallization are characteristic of quartz in low-grade metamorphic rocks (Young, 1976). A sedimentary source is indicated by siltstone, sandstone, chert and extremely well rounded quartz (Fig. 2a).

Precambrian granitic plutons and metamorphic rocks and Cambrian alkalic plutons of southern New Mexico are the most probable source for Bliss sandstones. The abundance of QFF is not only a good indicator of a granitic source but also that the source is local. Quartzo-feldspathic rock fragments are relatively unstable and do not survive long transport and extensive winnowing (G. H. Mack, oral commun. 1985). The upsection decrease of QFF may be the result of extensive winnowing of Bliss sandstones. Metamorphic rock fragments are most abundant where the Precambrian rocks are metamorphic. Detrital plagioclase compositions are very similar to those from metamorphic rocks of southern New Mexico.

The siltstone and sandstone fragments are most likely intraformational. These fragments are common lithic types in the Bliss and they are large and subangular. They also occur most commonly in those sequences interpreted as storm deposits.

Volcanic rock fragments are present in sections from the Franklin Mountains. The source of these lithic grains is probably the Thunderbird Rhyolite which crops out in the Franklin Mountains. The grains are large, angular and stained, indicating the presence of potassium. The Thunderbird Rhyolite is a low remnant mountain which stood above the floor of Early Ordovician seas and served as a source of detritus for these seas (Kottlowski et al., 1973). Volcanic rock fragments are common in the El Paso Formation as well as in the Bliss in the Franklin Mountains.

Precambrian and Cambrian rocks of southern New Mexico are considered to be the source of detritus for sandstones of the Bliss Formation. Other detrital grain trends are an upsection increase of MXQ and a decrease of PXQ (Table 1). These trends are possibly due, in part, to the mechanical instability of PXQ. The increase in MXQ may be due to the stable nature of the grains as well as the unstable nature of QFF which break up to yield MXQ and feldspars.

TECTONIC SETTING

On QFL diagram, Bliss sandstones plot in the zone of continental block provenance (Fig. 3). Detritus from non-orogenic continental blocks is derived from the broad areas of stable cratons (Dickinson and Suczek, 1979). High ratios of KSP to PLG and high percentages of quartz reflect intense weathering on cratons and prolonged transport along continental surfaces with low gradients (Dickinson and Suczek, 1979). The Bliss Formation was deposited nonconformably on Precambrian rocks of southern New Mexico and west Texas. Locally, in the Florida Mountains it is nonconformable on Cambrian granite and syenite. The tectonic setting of the Precambrian is not well understood but a rift model is the most widely accepted paradigm for Late Precambrian tectonics of the western United States (Condie and Budding, 1979). Rock-type distributions and relative proportions (Schwab, 1971) of Precambrian

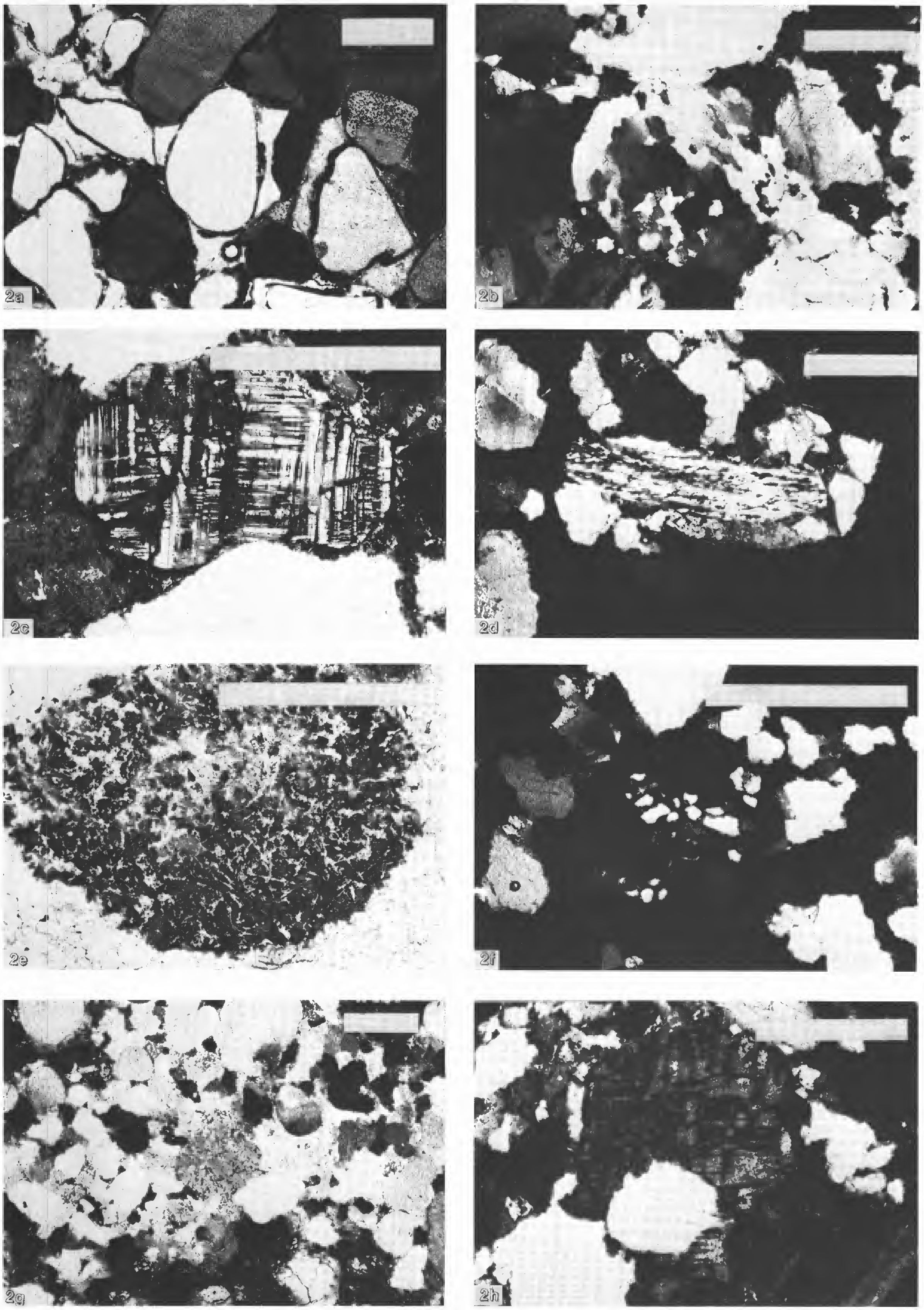

FIGURE 2. Detrital grain types of the Bliss Formation. A, Monocrystalline quartz (bar is 0.34 mm) displaying microlites as well as euhedral silica overgrowths accentuated by hematite dust rims. B, Polycrystalline quartz grain (bar is 0.13 mm) with undulatory extinction of crystal units. C, Microcline grain (bar is 0.5 mm) showing characteristic tartan twinning. D, Metamorphic rock fragment with long axis equal to 1.4 mm (bar is 1.0 mm). E, Volcanic rock fragment from a rhyolitic source (bar is 0.31 mm). F, Pelitic rock fragment—a siltstone rip-up clast (bar is 0.3 mm). G, Chert grain in center of photo (bar is 0.3 mm). H, Quartzo-feldspathic rock fragment (bar is 0.25 mm).

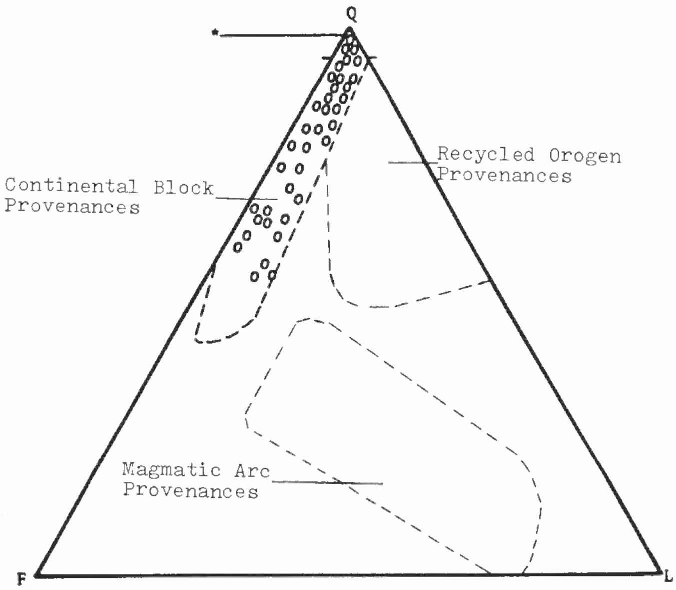

FIGURE 3. QFL plot of Bliss sandstones, which plot in the zone of continental block province. Q=MXQ and PXQ; F=KSP and PLG; L=CHT, PRF and VRF, following Dickinson and Suczek (1979). Asterisk denotes the position of 17 superimposed data points.

rocks in the southwestern United States most closely resemble that of a continental rift system (Condie and Budding, 1979).

Lower Paleozoic rocks of southwest New Mexico and west Texas represent a typical miogeoclinal assemblage due to the south-southwest thickening and the lithologic successions. The absence of volcanic detritus in this area precludes lower Paleozoic rocks from being a eugeoclinal assemblage. The terrigenous detrital sequence of the Bliss is a cratonal phase and may be related to erosion of an uplift created by thermal expansion during Precambrian continental rifting of what is now Nevada and Utah (Stewart and Poole, 1974). Deposition of terrigenous detritus probably stopped due to the destruction of this bulge by erosion and thermal contraction. This, along with a eustatic sea level rise, allowed carbonate deposition to occur as the siliciclastic facies were moved northward. The carbonates of the El Paso Formation may represent this change.

The Precambrian-lower Paleozoic succession of southern New Mexico and west Texas may represent the transition from a rifted setting to a passive or Atlantic-type margin. This is similar to lower Paleozoic miogeoclinal assemblages of the southwestern United States.

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