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Anna K. Worden

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Comparison of Breien and Cannonball Volcanic Tuffs in Southern North Dakota

by

Anna K. Worden

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ABSTRACT

Comparison of Breien and Cannonball Volcanic Tuffs in Southern North Dakota

by Anna K. Worden

Thesis Advisor: Dr. Nels Forsman
Department of Geology and Geological Engineering

Volcanic tuffs of Cretaceous age are found sandwiched in many outcrops in southwestern North Dakota. The lateral extent of many of these tuffs has been mapped, but distinguishing discrete tuffs is a work in progress. This report looks at two tuffs found along the Cannonball River south of Bismarck.

The Breien Tuff was collected in southeastern Morton County and the Cannonball Tuff was collected in northwestern Sioux County, but research had not yet been done to determine whether these two tuffs are distinct, or if one is merely an extension of the other. The proximity of the two sample sites allows the possibility that the Breien Tuff may be an extension of the Cannonball Tuff.

In order to distinguish the tuffs multiple comparative and analytical tests must be performed on both tuffs. Conclusions were made about the possible distinction or correlation of the Cannonball and Breien Tuffs using grain size analysis, x-ray diffraction, magnetic separation, and grain mount petrographic analysis.

The Breien and Cannonball Tuffs have few different properties when examined by the unaided eye. By the methods available for this research, insufficient evidence was found to show that the Cannonball Tuff and Breien Tuff were from the same depositional episode. However, further analytical tests of the two tuffs could determine the distinctness of these two tuffs. Scanning electron microscopy, as well as trace element and glass grain chemical analysis are some methods that could further the fingerprinting of these tuffs.

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INTRODUCTION

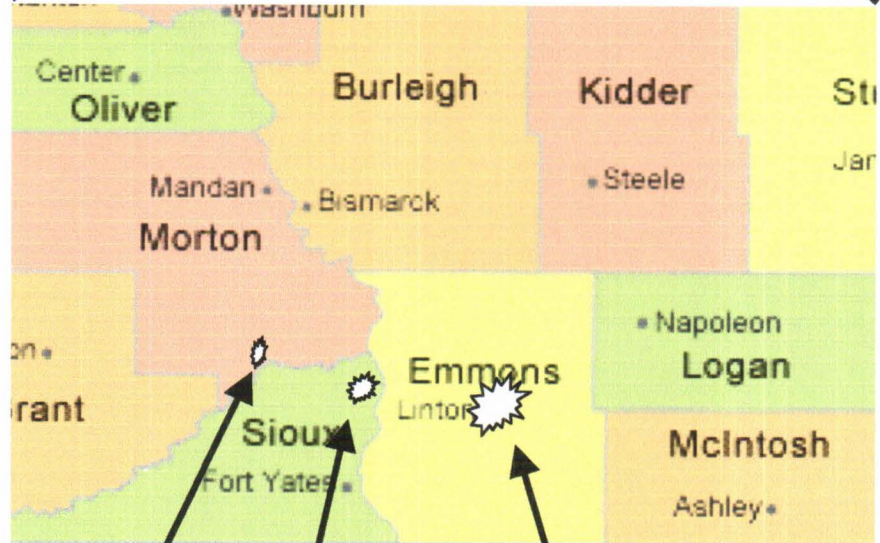
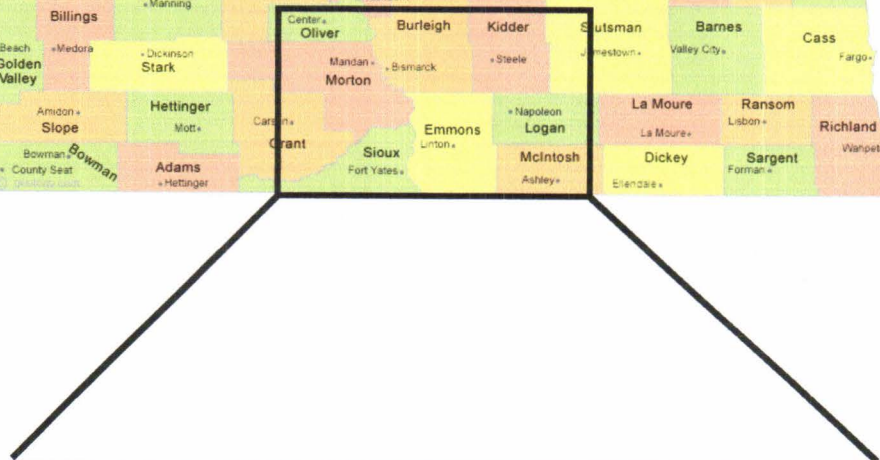
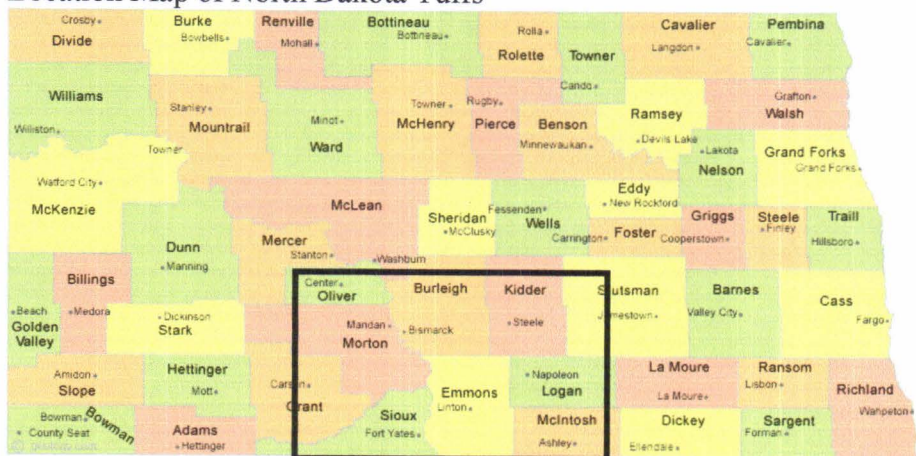
Introduction and Objectives

The location of interest for the Breien Tuff is located in the Southwestern region of North Dakota (SW $\frac{1}{4}$, NW $\frac{1}{4}$, Section 30, T134N, R81W). It can be reached by traveling South 30 miles on ND6 from Bismarck, ND and is located east of the town of Breien, ND.

Another tuff, named the Cannonball, has been collected at SW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, Section 9, T133N, R79W (Figure 1). The Cannonball Tuff collection site is located approximately 14.5 miles from the collection site of the Breien Tuff (Murphy, 2005). The Cannonball was collected by Ed Murphy and the Breien was collected by Ed Murphy and Nels Forsman.

The Breien and Cannonball Tuffs have been analytically compared for the purpose of determining if there is sufficient evidence, through these techniques, to distinguish them as representing separate airfall events.

Figure 1:
Location Map of North Dakota Tuffs



Breien
Tuff

Cannonball
Tuff

Linton Tuff

Previous Research

Previous research, mapping, and analysis of tuffs in North Dakota and their glasses has been carried out by Nels F. Forsman. Additional mapping and collection has been done by Edward C. Murphy.

In North Dakota there are many mapped tuffs. One of the largest is the Sentinel Butte Tuff. The tuff nearest my study area is the Linton Tuff. This tuff has been mapped in Emmons County, North Dakota. First discovered near the town of Linton, North Dakota this tuff is at least eight meters thick in some exposures. It is located near the contact between the Upper Cretaceous Pierre Shale and the Fox Hills Formation (Forsman, 1983). Murphy has mapped all tuffs sampled in this area of North Dakota, though they have not all been specifically named. The Linton Tuff is found approximately 35 miles from the location where the Breien Tuff was collected and 20miles from where the Cannonball Tuff was collected. The Cannonball and Breien Tuffs are also accepted to be Cretaceous in age.

Field Methods

Field work was conducted in order to become personally familiar with the outcrops of interest and to obtain some additional samples. Outcrops were found by using NDGS

maps (Murphy, 2005). The sampled outcrop of Breien Tuff is located in and around the barn of a private residence along Highway 6. This site was visited in order to become familiar with the tuff in situ.

Laboratory Methods

Sample Preparation

Samples collected by Forsman and Murphy were separated into two test batches. The collected Breien Tuff was named Sample B, and the collected Cannonball Tuff was named sample CB.

Samples were disaggregated using an ultrasonic bath along with numerous decantations of suspended clay. The disaggregated and clay-free sample was then collected, stored, and used for subsequent testing.

Oil Emersion Slides

Oil emersion slides of all the samples were prepared in the following way. Oil with a refractive index of 1.545 was placed on a clean slide. A small amount of grains from a sample were brushed onto this slide and a cover slip was placed overtop. These slides were viewed under a polarizing microscope in order to identify and distinguish glass and mineral grains. This method was also used to see if clay had been sufficiently washed

away from the glass grains. The glass grains are a key component in classification of a specific tuff.

Textural Analysis

Grain size analysis was done to determine the size mode and range of tuff constituents. Results were recorded for sample CB as well as sample B. These characteristics are presented in Table 1.

Glass Grain Separation

A Frantz Iso-dynamic Magnetic Separator was used in order to isolate glass grains. Vibrating the sample while subjecting it to electromagnetic forces separates the magnetic and non-magnetic components. Trial and error is involved with this method to insure the most complete separation possible.

Portions of Sample B and Sample CB <74 μ were passed through this device. After the first pass through the magnetic separator, the portion with the highest non-magnetic (highest glass) content was run through again to further separate glass. This method was carried out multiple times, and at amperages ranging from 0.8 to 2.0, in order to insure glass and mineral separation. The magnetic separator is also tilted in two directions. The first direction of tilt is front-to-back. This tilt angle was set at **20°**. The second tilt setting is a side-to-side setting. This angle was set at 15°. For each subsequent run the separator was set at different amperage search for an optimum setting to achieve glass isolation from crystalline components.

Grain Mounts

Grain mounts were made by placing a small amount of Canada Balsam with Xylene on a slide. A small amount of sample grains were then brushed on and a cover slip was applied. The entire slide was then placed on a hotplate to heat the Canada Balsam, allowing the xylene to bubble off while the remaining Balsam hardens. With oil emersion slides it is possible for the grains to move around as the oil moves or evaporates. With grain mounts the grains stay put because the Canada Balsam hardens almost immediately. These slides can be used for accurate grain counts.

Results

Results

Sample Examination

The Breien Tuff collected by Forsman was divided into two samples. One sample (A) was soaked in distilled water in order to remove clay from the grains. The other sample (B) was put through an ultrasonic bath in order to disaggregate the material as well as to separate the clay coating from the glass grains. The technique used on Sample A did not sufficiently remove clay from the sample, and therefore Sample A was not used for any further purposes. Sample B's ultrasonic bath treatment was very effective in removing clay from the glass grains. Sample B was then used for further study.

A portion of the collected Cannonball Tuff, Sample CB, was washed ultrasonically, similar to Sample B. This sample received identical treatment to that used for Sample B. This assures that similar data was gathered from each tuff.

Oil Emersion Slides

Oil emersion slides of Samples A, B, and CB were made in order to observe the glass grains. The majority of the glass grains in these tuffs are broken vesicle walls, ranging in size from 40 μm to 100 μm .

The oil emersion slide of Sample A showed that clay had not sufficiently been cleaned of this sample. Because of this finding, Sample A was no longer tested along side Samples B and CB. Both Samples B and CB appeared sufficiently clay free to proceed with further treatment.

Textural Analysis

The method chosen for grain size analysis was the sieve method. For this test the cleaned samples were run through sieves decreasing in size from 200 mesh (74µm) to 400 mesh (37 µm). This test was repeated multiple times in order to obtain a mean grain size (Tables 1 and 2). The sieve test for each sample was done with a starting weight of 1 gram. The tests for both samples resulted in fairly low percent errors, less than 3% for each test.

Sample B (table 1) had very little material larger than 74 µ (10%). The majority of the material fell into the >44 µ sieve (76%). The remaining material (15%) was retained by the 37µ sieve. The result of sieve test of Sample CB (table 2) were 19% >74µ, 73.6% >44µ, 10% >37µ, and 0.6% <37µ.

Table 1:
Mean Sieve Analysis (1 gram Sample B)

Sieve # (mesh)	Diameter (µm)	Sediment Retained (g)	Percent Retained
200	74	0.1	10%
325	44	0.76	76%
400	37	0.15	15%
Pan	<37	0.0	0%
Totals		1.01	101%

(1 Percent Error)

Table 2:
Mean Sieve Analysis (1 gram Sample CB)

Sieve # (mesh)	Diameter (μm)	Sediment Retained (g)	Percent Retained
200	74	0.19	19%
325	44	0.736	73.6%
400	37	0.1	10%
Pan	<37	0.006	0.6%
Totals		1.032	103.2%

(3.2 Percent Error)

The biggest noted difference between Sample B and Sample CB was the amount of largest and smallest sized grains present. Sample CB had notably more material $>44\mu$, though this is most likely not due to separate airfall events. The majority of these grains are glass grains. These larger glass grains commonly contain ovoid or spherical vesicles. These results suggest that Sample CB has a higher proportion of large glass grains than Sample B. This difference in size distribution is most likely a result of deposition or transportation.

Magnetic Separation

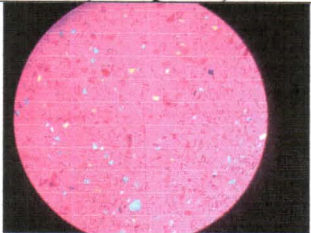
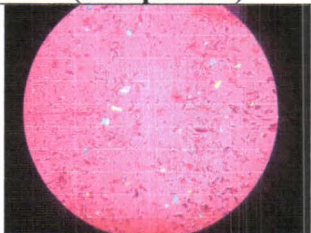
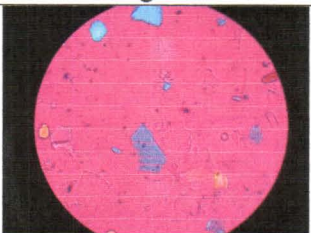
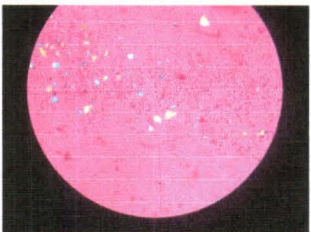
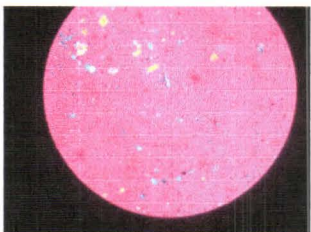

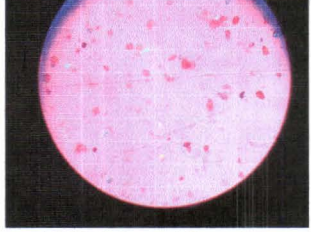
Separation of the magnetic and non-magnetic material was deemed sufficient. By looking at brushed grains under a petrographic scope, it was easy to determine that sufficient separation had taken place. The results of the magnetic separation can be seen by examining grain mount made from the separate fractions. The non-magnetic fraction of the samples was almost completely glass grains. The magnetic fraction contained a high concentration of micas, both muscovite and biotite.

Grain Mounts

Three sets of grain mounts were made. One set was made of portions of Sample B and Sample CB that had been disaggregated, but not magnetically separated. The second set of grain mounts were made of the non-magnetic portions of Sample B and Sample CB after being run through the magnetic separator. The third set was made with the magnetic portion of the samples run through the magnetic separator. These three sets were made in order to do point counts of glass and other grains. By comparing point counts of the raw and separated samples, a more detailed comparison can be made. Photos taken of all the grains mounts can be seen in Figure 2.

The minerals identified in the samples were classified as spherical glass, tubular glass, plagioclase, muscovite, and biotite. Spherical glass was classified by its ovoid or spherical shaped vesicle walls. Tubular glass contained tubular or pipe-like vesicles, as opposed to spherical. Plagioclase grains were classified by locating grains that exhibited polysynthetic twinning, which gives it a striped appearance. Muscovite and biotite were differentiated by making note of color in plain and cross polars. The biotite grains were also compared to a known biotite standard.

Figure 2:
Petrographic Scope Grain Mount Pictures
(Cross Polars with Gypsum Accessory Plate)

Condition	Breien Tuff (Sample B)	Minerals Present	Cannonball Tuff (Sample CB)	Minerals Present
Bathed Ultra- sonically	 10X Magnification	Glass (67.0%) Plagioclase (1.5%) Muscovite (29.5%) Biotite (2.0%)	 10X Magnification	Glass (73.0%) Plagioclase (1.0%) Muscovite (20.0%) Biotite (6.0%)
	 40X Magnification			
Magnetically Separated (Non- Magnetic Portion)	 10X Magnification	Glass (66.5%) Plagioclase (1.0%) Muscovite (32.5%) Biotite (0.0%)	 10X Magnification	Glass (65.5%) Plagioclase (0.5%) Muscovite (34.0%) Biotite (0.0%)
Magnetically Separated (Magnetic Portion)	 10X Magnification	Glass (5.0%) Plagioclase (0.5%) Muscovite (66.5%) Biotite (28.0%)	 10X Magnification	Glass (3.5%) Plagioclase (0.0%) Muscovite (47.5%) Biotite (49.0%)

The grain mounts made of Samples B and BC that only went through the ultrasonic bath looked very similar. Both samples contain glass grains, some muscovite and biotite, and plagioclase. The complete results of point counts done on these mounts can be seen in Table 3.

Table 3:
Point Count Results (Pre-Magnetic Separation)

MINERAL	SAMPLE B		SAMPLE CB	
	COUNT	PERCENTAGE	COUNT	PERCENTAGE
GLASS (spherical)	124	62.0	119	59.5
GLASS (tubular)	10	5.0	27	13.5
PLAGIOCLASE	3	1.5	2	1.0
MUSCOVITE	59	29.5	40	20.0
BIOTITE	4	2.0	12	6.0
TOTAL	200	100.0	200	100.0
TOTAL GLASS	134	67.0	146	73.0

Grain mounts made of the non-magnetic separate showed similarities between Sample B and Sample CB as well. These mounts included glass, muscovite, and some plagioclase. All of the biotite had been removed from the non-magnetic sample. The complete results of point counts done on these mounts can be seen in Table 4.

Table 4:
Point Count Results (Magnetically Separated, Non-Magnetic Portion)

MINERAL	SAMPLE B		SAMPLE CB	
	COUNT	PERCENTAGE	COUNT	PERCENTAGE
GLASS (spherical)	113	56.5	101	50.5
GLASS (tubular)	20	10.0	30	15.0
PLAGIOCLASE	2	1.0	1	0.5
MUSCOVITE	65	32.5	68	34.0
BIOTITE	0	0.0	0	0.0
TOTAL	200	100.0	200	100.0
TOTAL GLASS	133	66.5	131	65.5

The magnetic separate showed the greatest differences in the two tuffs. In these samples the glass and plagioclase had been nearly completely removed. There were very high concentrations of both biotite and muscovite in each sample, although their proportions were dissimilar. Sample B contained 66.5% muscovite and 28.0% biotite. Sample CB contained 47.5% muscovite and 49.5% biotite. These findings will be discussed as a possible difference between the tuffs in the conclusions. The complete results of point counts done on these mounts can be seen in Table 5.

Table 5:
Point Count Results (Magnetically Separated, Magnetic Portion)

MINERAL	SAMPLE B		SAMPLE CB	
	COUNT	PERCENTAGE	COUNT	PERCENTAGE
GLASS (spherical)	6	3.0	7	3.5
GLASS (tubular)	4	2.0	0	0.0
PLAGIOCLASE	1	.05	0	0.0
MUSCOVITE	133	66.5	95	47.5
BIOTITE	56	28.0	98	49.5
TOTAL	200	100.0	200	100.0
TOTAL GLASS	10	5.0	7	3.5

CONCLUSION

Discussion

Size Distribution Differences

As recorded earlier, a slight difference in grain size distribution was found. This discrepancy however, does not point exclusively to separate airfall events. Many things can affect grain size distribution in a sample. In these two tuffs, the grain size distribution is due to depositional factors, as well as any subsequent weathering of the area.

Mica Differences

The differences seen between tuffs in the grain mounts is not proof that these tuffs originated from separate eruption events. The mica was most likely deposited into the tuff at some later date. This could be done by wind or water deposition. The Breien Tuff and Cannonball Tuff collection sites were approximately 15 miles apart. This would allow for different proportions of mineral to be deposited in each area. This would allow for different proportions of minerals to be deposited in each area, due to different tributary systems eroding different terrains or different outcrops supplying wind transported sediments. It is possible that one setting was conducive to accumulating eolian silt, while the other locations was not.

Conclusions

With the techniques and methods available to me I have found no evidence that suggests a similar origin for the Breien and Cannonball Tuffs. All the noted differences between the tuffs can be explained without concluding that one airfall event deposited both tuffs. Other laboratory methods may be able to find a distinction between these tuffs, but the methods available for this study did not detect adequate evidence of distinction.

Additional Methods for Further Research

There are many more techniques available for the fingerprinting of a volcanic tuff. The research completed on the Breien and Cannonball Tuffs was primarily optical examination. There are many other tests that could further the information known about these two tuffs. Unfortunately for this research project, adequate funds, as well as time, were not available. For this reason, the results presented here can be vastly improved upon.

X-Ray Diffraction

X-Ray diffraction (XRD) analysis could be done to classify the types of clays found in the sample. The slides used for x-ray analysis would be made with suspension decanted from disaggregation of the sample. This decantation would contain the clays that held the tuff together. In x-ray analysis samples are mounted on a slide and then bombarded with

x-rays. XRD could be run on dry slides as well as slides that had undergone ethylene glycol salvation. This analysis can be used to determine the mineralogy of the clays. If the two samples are bound by different clay types, then they may possibly be distinct tuffs. Clays are formed in tuffs as water seeps through the layers. The type of clay that forms depends slightly on the chemistry of the water running through them. By looking at the XRD results it would be possible to further classify the tuff. This information could be important in distinguishing the Breien Tuff from the Cannonball Tuff.

The clays binding the Breien Tuff are montmorillonite. The clays binding the Cannonball Tuff have not yet been tested but are most likely also montmorillonite. These results would be comparable to other tuffs in the region.

Scanning Electron Microscope

An SEM can be used to look closer at the glass grains isolated from the magnetic separation. The SEM creates high-resolution, high magnification images of a sample surface. These pictures of individual grains would aid in the comparison of morphologic signatures within a specific tuff. These signatures can be compared to other tuffs of known origin. This could distinguish tuffs of different magma mineralogies.

Trace Element and Mineral Analysis

Possibly the most accurate method to fingerprint a volcanic tuff is to analyze the chemical constituents including the trace elements present. Each volcanic eruption event

will create a tuff with slight differences in chemical and mineral composition. Though these differences are not visible by petrographic means, they can be examined with scanning electron microscopes/microprobes or other elemental analysis instrumentation.

Phenocryst Analysis

Another method that could provide more information about a specific tuff is by examining phenocrysts found within the tuff. This method is pivotal in precise mineralogic characterization of tuff deposits, as well as the magma they originated from. If phenocrysts were found in either the Breien or Cannonball Tuffs they could possibly distinguish or correlate the tuffs. There can be some complications with this method, though. The phenocryst would have to satisfy one of three conditions. The phenocryst could have euhedral form. This would appear in both SEM and petrographic scopes as a mineral with crystal form. A phenocryst could also be subhedral. These crystals will show some crystalline edges paired with a broken edge. These euhedral and subhedral grains would have formed from the magma at the time of eruption. By analyzing these grains, one would get the most precise information about the original magma. The last group of phenocrysts would have to have glass grains connected to or growing from it. If glass is not directly related to the phenocryst, one cannot tell if the suspected phenocryst grain is from the original eruption of the ash, or if it is a wind blown inclusion. Tuffs are susceptible to the wind blown inclusions due to the time required for deposition as well as the style of deposition. Anything blown in from the surroundings when the ash was deposited would be included in the ash, and therefore would be included in the tuff. At

least one of these conditions must be satisfied, although more than one are possible at the same time.

The information gained from phenocrysts would aid in the classification of a magma type for each tuff. If two tuffs originated from different mineralogies of magma, the tuffs must be two discrete tuffs. This method is perhaps the most definitive test to distinguish tuffs from one another. In the Breien and Cannonball Tuffs, no phenocrysts were located. Only a relatively small portion of the tuffs were examined, so there is still the possibility of phenocryst location and characterization.

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