PLANAR DEFORMATION FEATURE ORIENTATIONS AND DISTRIBUTION IN QUARTZ GRAINS FROM THE CARRIZO SAND FORMATION IN SOUTH TEXAS: RELATION TO THE BEE BLUFF STRUCTURE. D.J. Jurena[1], B.M. French[2], and M.J. Gaffey[1] ,[1]Rensselaer Polytechnic Institute, Planetary Sciences Laboratory, 2C01 Science Center, Troy, NY 12180, jurend@rpi.edu, [2]Dept. of Mineral Sciences, MRC 119, Smithsonian Institution, Washington, DC 20560, French.Bevan@nmnh.si.edu.

The Bee Bluff structure, a 2.4 km diameter circular feature in the Carrizo and Indio formations is located 22 km south of Uvalde, Texas, has been investigated by several groups in the past and its origin has been debated even though planar deformation features have been found. Wilson and Wilson [1] did find anomalous structural features in the area that they attributed to impact processes and P.B. Robertson [2] found PDF's in a quartz grain that are consistent with impact. Further investigation by V.L. Sharpton and D.C. Nielsen [3] found a small percentage of the sandstone grains from the structure contained planar features with orientations corresponding to the ω {1013} and r,z {1011} orientations. They also found in samples taken from the same formation further to the east a similar orientation pattern of planar features in quartz grains which led them to conclude that the shocked quartz had an origin not uniquely connected to the formation of the Bee Bluff structure. However, planar features with an r,z orientation are consistent with impact structures in porous sedimentary rocks [4], the same type that are in this area. While the ω orientation is usually suppressed in favor of higher angle orientations, this is not always the case especially where the quartz grains are tightly interlocking [4]. Since the PDF orientation diagram from Sharpton and Nielsen [3] was a composite of several samples from different locations in the structure, we examined several samples from the structure and from outcrops of the same formations located across south Texas. Our goal was to investigate not only the distribution of the shocked quartz in the Carrizo and Indio formations, but also if the planar feature orientations varied within the Bee Bluff structure as they do at Gosses Bluff [4]. At the latter location, the ω orientations are dominant in tightly interlocking sandstones in contrast to the more porous sandstones where the higher angle planar orientations include should be sized to fit into a single column.

Outcrop exposures: During our initial investigation, we have found a discrepancy in the location of the outcrops as plotted on the geologic map of Wilson [1] versus those that we did find on other maps and in the field. Wilson's "Impact Area" was approximately circular in shape. However, in order to include some outcrops that were originally part of the southern outline, the structure's shape would have to be significantly distorted from circular. From further study of aerial photos, maps, and field outcrops, we have found that a better match to a circular outline is made if the outcrops on the southwest and eastern edges are remnant exposures of an outer margin expressed in photos as a lighter shaded ring. These outcrops may have been more continuous in the past but are now eroded and partially buried leaving only the lighter shading in photographs as their expression. The one large exposure that Wilson [1] had as part of the southern edge better fits as part of the central area which is seen in the aerial photos as a lighter shaded circular area within the previously mentioned ring. This reinterpretation shifts the position of the structure about 1 km to the south southeast.

Planar Deformation Features: Samples of the Carrizo and Indio formations were collected from outcrops located throughout south Texas. Both of these formations crop out in a parallel band that stretches eastward to just south of San Antonio and then they trend towards the northeast. This outcrop also extends just to the west of the structure and then trends southward. Thin sections of these sandstones and shales were examined primarily for PDF's but in addition we also looked for other signs of impact processes such as diaplectic glass and lechatelierite.

In the thin sections we found that 7.5% to 12.6% of the quartz displayed PDF's. Additionally, some of these same grains also exhibited mottled extinction to varying degrees. The PDF's were measured on a universal stage and the planes were then indexed using an overlay from Stoffler and Langenhorst [5]. From the samples collected at the edge of the structure (LRE-02, LRE-11, HW-03), the orientation and frequency of the PDF's is consistent with impact structures formed in porous sedimentary targets [4] where ω and π plane frequencies are reduced relative to higher angle planes such as ξ which here has a frequency range of 25-32%. A sample collected near the center of the structure (LRE-10) departed from this trend with an ω orientation being the most common at 28% which is characteristic of planar features from crystalline targets and sandstones whose grains are tightly interlocking.

To the east of the structure while there are PDF's in some of the quartz grains, in no case have we found in any sample a single planar orientation with an occurrence frequency of over 18%. Also, in relation to the

Bee Bluff structure, there are fewer quartz grains with PDF's in the Carrizo formation outside the structure compared to the quartz grains at the structure. With sample #4 which is located 26 km to the east of the structure, the ξ and π planes have a frequency of 18% which is significantly greater than the other planar orientations that are present. Another sample collected 87 km to the east (MK-7) has three dominant plane orientations of ω, ξ, and s which is an unusual orientation occurrence for either porous or crystalline targets. In addition, the frequency percent of these three prominent planes is similar to the frequency percent of the prominent plane orientations for the previous sample. PDF's were also found in #7 located 60 km to the south of the structure. While we did index 27 sets of planes, no particular plane orientation occurs more frequently than the rest. The only trend noticeable from this is a slightly increased frequency for orientations of higher angles than ξ which is similar to the orientation distribution of healed fractures [6].

PDF Frequency: Since not all of the quartz grains display planar deformation features, we measured the number of quartz grains having PDF's versus the total number of quartz grains present in each sample. In doing so, one must take into account that in porous rock impact structures not all of the quartz grains will develop planar features as noted by Robertson [2] where they can be "considerably less abundant" or only 5% of the quartz grains have planar features as a Barringer [7]. Thus even in the most shocked rocks of porous targets one may not find PDF's in all of the quartz grains. Two of the samples from the structure (LRE-10, LRE-11) had 12.6% and 12.0% respectively of the quartz grains exhibiting PDF's. In a third sample from the structure, LRE-02, 8.9% of the quartz grains exhibited PDF's. This lower frequency with respect to the Indio formation which is composed of finer grained material that may not have been as conducive to PDF development.

In contrast, there were fewer PDF's from samples outside the structure. For instance, in sample #4, 8.7% of the quartz grains exhibited PDF's and only 8.3% of the quartz grains in sample MK-7 did as well. This decreasing frequency of quartz grains with PDF's may have been the result of transport of shocked quartz from a point source in the vicinity of the Bee Bluff structure or it could be an ejecta deposit. In order to get a better constraint on this source, we looked at two samples collected 30 km to the west (#3) and 60 km to the south (#7) of the structure. Although PDF's were found in both samples (7.7% and 7.5% respectively), the frequency is less than that found in the other samples. Taking into account the orientation data on #7 which did not show any pattern associated with impact structures or of any other sample in this study suggest that the PDF's measured in #7 may have another unique source. Sample #3 which has a similar percentage of quartz grains with PDF's may also be derived from this source.

Synthesis: Given that the Carrizo samples from the structure had the highest percentage of PDF's indicates that the source for these is nearby and was introduced to the Carrizo sediments before they became lithified or a given region of the Carrizo sediments experienced a shock event before the transport of the future Carrizo sandstone had ceased. If this is the case, then the PDF's found in samples #4 and MK-7 to the east of the structure may be the result of material transport in this area. In both samples there are fewer quartz grains with PDF's than the ones from the structure. Also there is a 0.4% decrease in the number of quartz grains having PDF's from #4 to MK-7. If it were just the case of shocked material being eroded from a source then one would expect the orientation patterns of the PDF's to be quite similar but they do not resemble a single given sample measured from the structure or even each other. Neither has as pronounced an ω and/or ξ plane orientation frequencies similar to the HW-03 or LRE-10 and LRE-11 sandstones, nor do they exhibit the relatively even planar orientation frequency distribution of #7. They may then represent mixtures of material transported from both within the vicinity of the structure and possibly material with planar orientations similar to #7.

Conclusion: While the results of this do not prove that the Bee Bluff structure formed by impact processes, this new evidence indicates that it should at least be reevaluated. The PDF orientation patterns measured thus far are consistent with that of other impact structures in porous sedimentary rocks. In addition, the percentage of quartz grains from these samples having PDF's is similar with some other porous sedimentary targets [2]. But since the PDF's are not confined to the structure alone, more information is needed before the actual source of the shocked quartz is identified. We are continuing to examine more samples in order to answer this question.

References: [1] Wilson, W.F., and Wilson, D.H. (1979) Geology 7, 144-146. [2] Robertson, P.B. (1980) LPSC XI, 938-940. [3] Sharpton, V.L. (1988) LPSC XIX, 1065-1066. [4] Greive, R.A.F. (1996) Meteoritics & Planet. Sci. 31, 6-35. [5] Stoffler and Langenhorst (1994) Meteoritics & Planet. Sci. 29, 155-181. [6] French B.M. et al. (1974) Geol. Soc. America Bull., 85, 1425-1428. [7] Kieffer, S.W. (1971) Jour. Geophys. Res., 76, 5449-5473.