Dear Dr. Gasperini and colleagues-

I am very interested in Impact Geology (my hobby), and I have been seriously studying your recent publications on the data and interpretations dealing with Lake Cheko and its relationship to the Tunguska event of 1908. You and your team should be commended on the quality of your research. The data you have generated will add greatly to our understanding of the effects on the geological structure of the Earth produced by the impact of extra-terrestrial bodies onto its surface. I hope your research efforts relative to the Tunguska event can continue.

I heartily agree that Lake Cheko is an impact structure, and I also agree that several cosmic objects traveling along an oblique impact trajectory less than 45° above the horizon impacted the area. However, I conclude that the Lake Cheko crater was formed by a single fragment significantly larger than others in a collection of fragments that could have broken away from a primary object due to atmospheric drag and gravitational forces.

Before proceeding with comments relating to the relationship between the Tunguska event and the formation of Lake Cheko, I want to alert you to my conclusions regarding the fundamentals of the impact cratering process. My research indicates that the much of the current literature reflects a poor to inaccurate definition of the processes involved which leads to many false conclusions derived from observations on geologic impact structures. I contend that the lack of understanding of the mechanics of impact crater formation throughout the Impact Geology and Impact Physics communities has also led to a long list of computer models that do not simulate all of the significant aspects of impact crater formation thus producing fundamentally inaccurate and many times unrealistic results. The fundamentals of hypervelocity impact cratering are very clearly indicated in published data, much of which is derived from the many laboratory scale experiments performed over the past fifty years, and I have collected my thoughts and conclusions regarding the processes that are observed to produce hypervelocity impact craters in a variety of materials in a paper that was published last summer in Northwest Geology.[1] A copy of this paper, TRGS 09 Revised.pdf, can be downloaded from: http://public.me.com/lburtlundberg by typing **titanium** into the Password field. My proposed model is based mostly on observational data rather than speculation or computations performed with computer models that do not accurately simulate the data on observed impact structures or the processes involved in hypervelocity impact crater formation. As this is a work-in-progress, I would be happy to hear your reactions to and comments on the referenced data and conclusions presented in this paper.

Based on the various data you have published and an accurate model of the impact cratering process, I conclude that the 'accepted/assumed' trajectory of the incoming impactor that created Lake Cheko and the observed tree fall pattern is off by 180°. The data you have presented indicate that the impactor trajectory was probably NW to SE

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[1] Lundberg, L. B., Impact Geology: Fundamentals of Impact Crater Formation, Northwest Geology, v. 38, 2009, pp. 67-88, Eds. B. E. Cox and R. I. Gibson.

rather than SE to NW, as is commonly assumed. The attached image (Figure 1) supports the revised impact trajectory because the mechanics of oblique hypervelocity impact forces the ‘butterfly’ ejecta deposition pattern…marked by the tree fall planform…to be skewed downrange from the impact point…Lake Cheko. The ‘butterfly’ planform is commonly seen, for example, around craters on Mars formed by low angle impacts.[2] The Tunguska tree fall pattern appears to be primarily caused by the blast wave that travels close to the impact target surface at the instant of impact…the “impact splash” phase of the cratering process (see Ref. 1). As the impactor disintegrates after initial impact and a steady shock wave is generated in the target material, the ejecta trajectories become confined by the walls of the developing crater and the shape of the primary shock wave to a conical sheet. This means that the trajectories of the crater ejecta will be well above the horizon during the formation of the primary (transient) crater, and the most of the ejecta from the crater will travel on a ballistic trajectory and

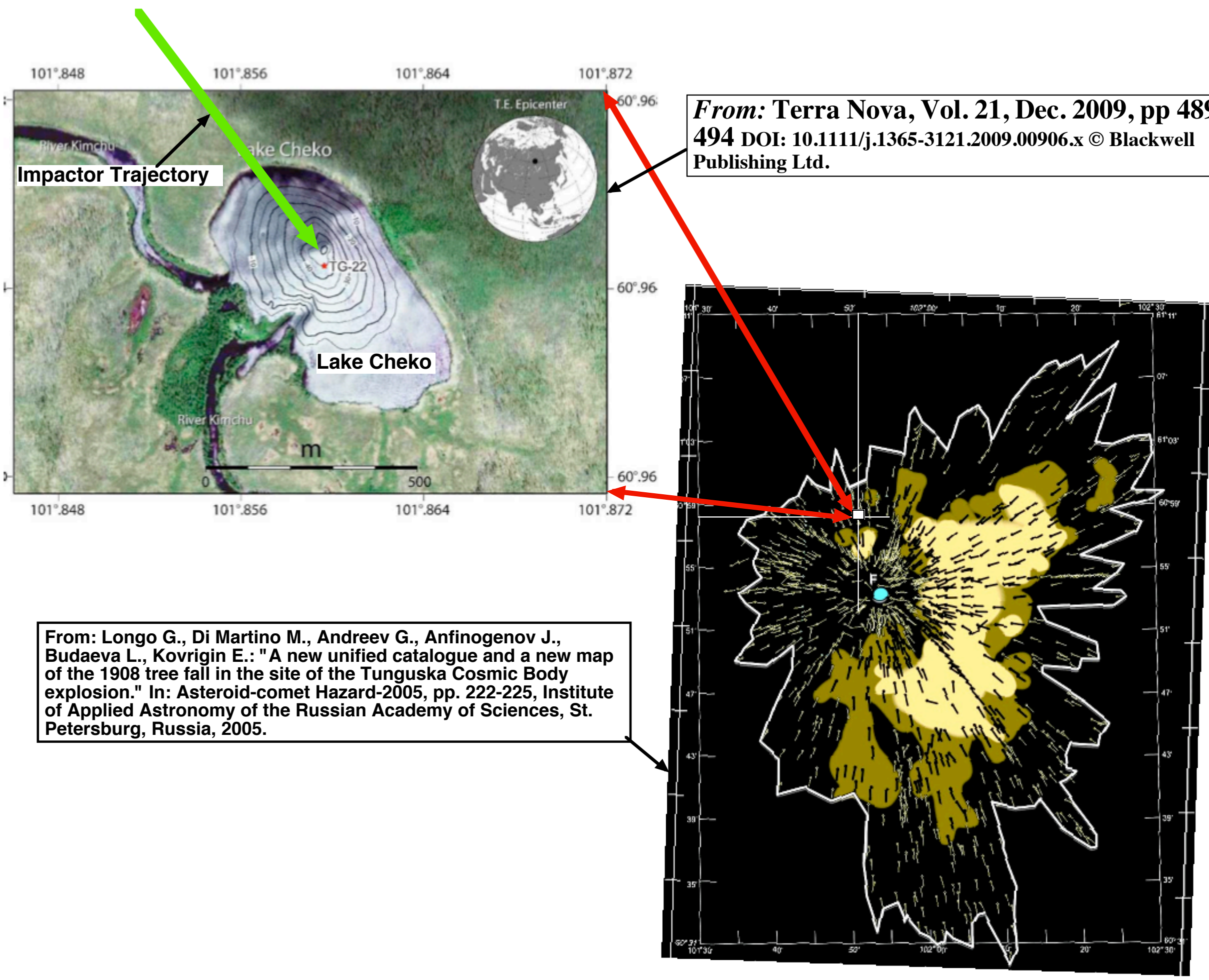


Figure 1. Map of Lake Cheko and surrounding area.

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[2] Herrick, R. R. and Hessen, K. K., The planforms of low-angle impact craters in the northern hemisphere of Mars, *Meteoritics & Planetary Science* 41, Nr 10, 1483–1495 (2006).

fall some distance from the primary crater. Fragments of the impactor will probably never be found in the bottom of the crater because most extra-terrestrial impactors disintegrate and mix with the ejecta during the primary crater formation process.

The overall shape and topography of Lake Cheko further defines the impactor trajectory. The up-range side of a hypervelocity impact structure is observed to be slightly higher with a steeper slope to the crater bottom than the downrange side. These and other significant morphological features observed in and around Lake Cheko … especially its elongated planform…are similar to those observed for hypervelocity impact craters formed in stainless steel,[3] for example. By analogy with the hypervelocity impact cratering behavior of a well known material such as stainless steel, it is possible to conclude that Lake Cheko was formed by an impactor trajectory that was closer to 20° above the horizon than the assumed 30° to 45°…see Fig. 4 in Ref. 2. The data also places the epicenter of the impact at the deepest point of Lake Cheko rather than at the assumed location southeast of the lake.

In addition, the morphology of the lake bottom is similar to that reported many years ago for a hypervelocity impact crater in high strength low alloy steel[4]…see Figure 2. You have indicated that the inside walls of Lake Cheko showed indications of steps or small scarps[5] like those formed on the inside surfaces of the hypervelocity impact crater in high strength low alloy steel seen in Figure 2. These steps and the associated shear cracks…indicated in Figure 2…result from the fact that brittle materials under confined compressive loads fail in shear along the lines of critical resolved shear stress.

The 'shock wave damage terminus' indicated in Figure 2 is clearly defined around hypervelocity impact craters formed in most competent (near-to-fully dense) materials. The peak pressure at the spherically expanding shock wave front drops below the shear deformation or fracture strength of the target material as the front travels past the shock wave damage terminus. Sonic or seismic velocity effects develop in the target material outside of the shock wave damage terminus. I suggest that a shock wave damage terminus is indicated for Lake Cheko by the "bottom-profile" low-frequency seismic reflection data presented in Fig. 5 of your 2007 paper (Ref. 5).

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[3]Gardner, D. J. and Burchell, M. J., Thick Target Hypervelocity Impact Crater Morphology: The Influence of Impact Angle, Speed and Density Ratio, Proc. Second European Conf. on Space Debris, ESA SP-393, pp. 481-486 (1997).

[4] Shockey, D. A., et al, "Damage in Steel Plates from Hypervelocity Impact. I. Physical Changes and Effects of Projectile Material," Journal of Applied Physics, Vol. 46, No. 9, September 1975.

[5] Gasperini, L., F. Alvisi, G. Biasini, E. Bonatti, G. Longo, M. Pipan, M. Ravaioli and R. Serra, A possible impact crater for the 1908 Tunguska Event, Terra Nova, 19, 245–251, 2007.

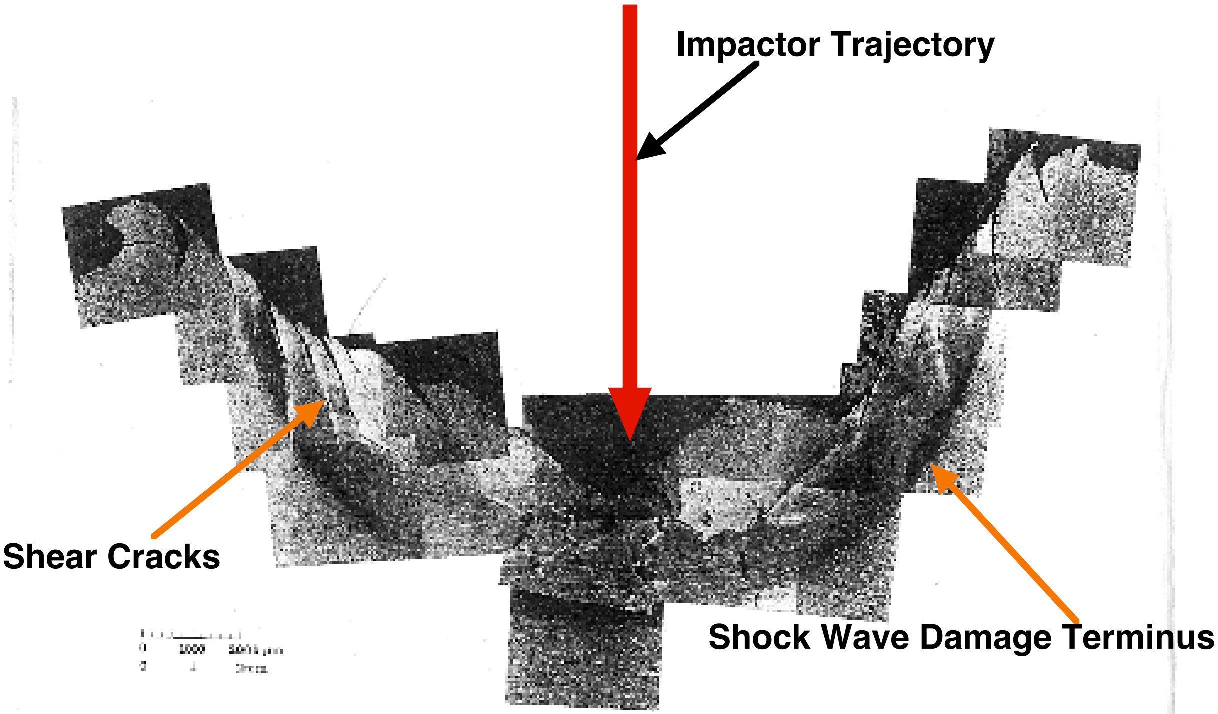


Figure 2. Montage of photomicrographs of the cross-section of a hypervelocity impact crater in high strength low allow steel impacted at 6.03 km/s with a water-filled polycarbonate sphere. (Original image copied from Ref. 4.)

Finally, the attack by Collins, et al[6] on your conclusions regarding the formation of Lake Cheko demonstrate the serious lack of understanding within the impact geology community of the fundamentals of the impact cratering process and the criteria for identifying impact craters on the surface of the Earth. The community that this group of 'experts' represents seems to consistently ignore data on the fundamentals of the impact cratering process derived from controlled, well instrumented hypervelocity impact experiments on simple materials…including hypervelocity impact experiments on competent rock. There is much left to be learned in the field of Impact Geology. Conclusions regarding impact structure formation must be consistent with <u>observational</u> data on the mechanics of the process.

Best regards,

Dr. Lynn Lundberg

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[6] Collins, G. S., N. Artemieva, K. Wünnemann, P. A. Bland, W. U. Reimold, and C. Koeberl, Evidence that Lake Cheko is not an impact crater, Terra Nova, 20, 165–168, 2008.