CAMPO DEL CIELO, ARGENTINA: WHEN WAS IT REALLY FORMED? A. Losiak[1], J. Plado[2], A. Jõeleht[2], M. A. Vesconi[3], D.P. Vesconi[3], A.P. Crósta[4], M. Saavedra[5], M. Bolka[5], P. Steier[5] [1]Institute of Geological Sciences, PAS, Poland (anna.losiak@twarda.pan.pl), [2]Department of Geology, University of Tartu, Estonia. [3]Asociacion Chaqueña de Astronomıa, O.N.G.P.J. 2555, Resistencia, Chaco, Argentina (mvesconi@gmail.com), [4]Institute of Geosciences – University of Campinas, Brazil; [5]Institute de Ciencias Astronomicas de la Tierra y el Espacio, [5]VERA lab, University of Vienna, Austria.

Introduction: Precise and accurate dating of impact craters is essential and challenging. Its significance lies in 1) our ability to correlate impact events with other geological processes such as major extinctions, 2) determination of the impact flux on Earth, and 3) gaining a better understanding of the overall history of the Solar System and our planet [1]. Out of ~200 impact-related structures on Earth, only twenty of them have either stratigraphic or isotopic ages with relative error <1% (e.g., Chicxulub and the Ries); an additional 36 have been dated with an error <2% [2]. However, even some of these "good" age determinations rely on a single method applied in a single paper, often published decades ago. One such crater strewn field, a crucial understanding of the Holocene impact flux on Earth [3] is Campo del Cielo (CdC) in Argentina [4,5], which age determination is based solely on three ^{14}C dates.

The current study **aims** to assess the validity of previous age determination of the CdC using an approach that has been successfully applied to determine the age and impact origin of Kaali [6], Ilumetsa [7] and Morasko [8], and to disprove impact origin of Tor [9], as well as show atypical properties of those charcoals [10].

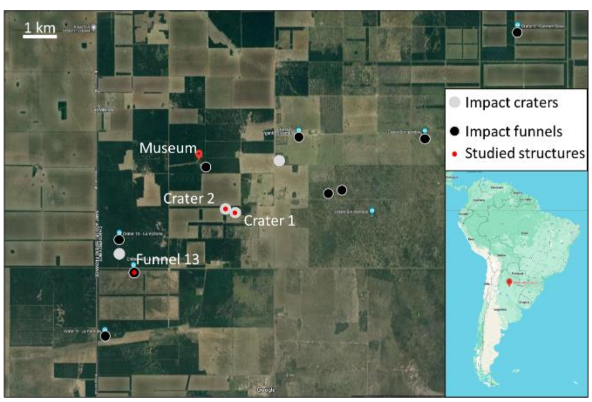

Fig. 1. A close-up of the central section of the Campo del Cielo strewn field (Chaco province, but not from Santiago del Estero). Trenched structures marked with red dots and described with name tags.

Campo del Cielo is a strewn field in northern Argentina, spanning ~18×3.5km and featuring four explosion craters and ~20 impact funnels [11,12,13,14,15,16,17]. The target consists of a massive loess devoid of any visible layering. An impact of octahedrite iron asteroid created CdC [4]. The asteroid likely weighed a minimum of 7500 – 8500 tons, with an entry velocity of 14.5-18.4 km/s and a shallow entry angle of 16.5° [18]. The impact angle was steeper (>25°) and impact velocity at the site was much lower, ranging 4-7 km/s for the largest structures to < 1km/s for the funnels [18,19]. Due to relatively low impact velocity, substantial meteorite fragments survived the landing. Visitors can admire multiple meteorite fragments at the outstanding Campo del Cielo Museum located at the discovery site of the Chaco meteorite (-27.6093°, -61.6813°). Notably, the museum houses (among several other large and small specimens) the ~28-ton Gancedo meteorite, found in 2016 by the Asociación de Astronomía del Chaco, which played a key role in establishing and managing the museum. It's truly a fascinating destination worth visiting! 😊

The previous age determination of CdC was summarized by Cassidy and Renard 1995 [5] (pp: 438; the ages in curly brackets are from Table 4): "From C-14 analysis of three charcoal samples, the age of the crater field was determined to be ~4000 years B.P. One sample was found in sediments infilling Crater 1 and assumed to be younger than the event {L-1043: 800±150}. The second sample was found in an ancient sub-soil below an ancient soil that had been buried by outthrown material from Crater 2, an explosion-analog-type crater: this sample was assumed to be the same age or older than the time of crater formation {L-746: 5800±200}. The third sample was found at the bottom of Crater 10, at the beginning of the tunnel. This sample was assumed to be the same age as the event {SI-1545: 3945±85}(Table 4)." No other publications have been released on this topic, and it is commonly assumed that CdC is one of the rare examples of precisely and accurately dated craters [1,2].

Methods; Fieldwork/sample collection: In the fall of 2022, we conducted nearly 3 weeks of fieldwork at the CdC sites. Trenching was performed in the proximal ejecta blankets of 3 structures (Fig 1): Crater 1 (one trench in the west) Crater 2 (two trenches, in the west and south), Funnel 13 (two trenches, in the west and east). The sites were selected so that trenches are arranged radially, penetrating a slightly risen rim of the structures (like in [6]) and located away from large trees. Trenches were dug by hand (and shovel) to a maximum depth of 2 m.

The structure of the ejecta blanket, as seen in the trenches excavated in Crater #2, appears massive and lacks any indications of ejecta-target contact or layering, as described by [4]. However, in both trenches of Funnel #13, a sharp contact was evident between a greyish organic-rich massive layer and a beige, zoned, probable paleosol beneath (Fig. 2).

Fig. 2. Trench 1 within Funnel #13 with the interpretation of the sedimentary sequence (including different types of boundaries).

We performed magnetic susceptibility measurements and sampled for detailed granulometric analysis to ascertain the boundary between the ejecta and the target (analysis is upcoming). We carefully noted and collected the position of all charcoal pieces in all the trenches (some of them to be dated by ^{14}C).

^{14}C dating at the Vienna Environmental Research Accelerator at the University of Vienna (Austria) [20] calibrated ages (95.4% probability) are calculated using the OxCal v4.4.4 IntCal20 atmospheric curve [21] and given rounded to 10 years.

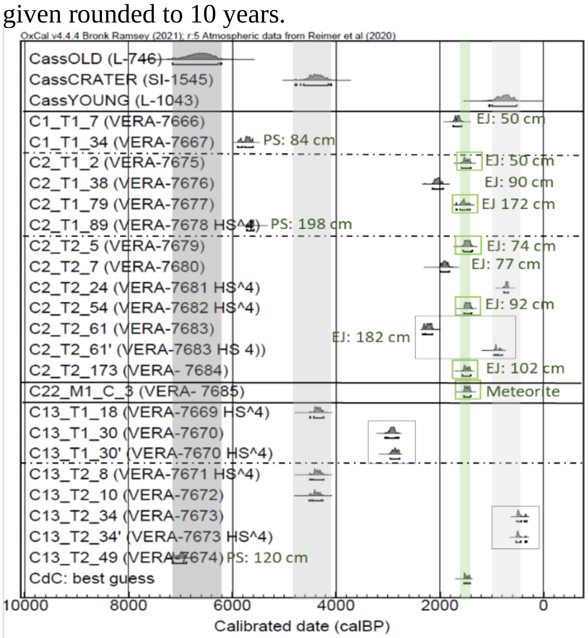

Fig. 3 Results of the ^{14}C dating of charcoals found within different locations of the CdC strewn field. The three first samples (starting with Cass) are for reference from [5]. Samples marked with C1 (one trench) and C2 (two trenches) are from explosion craters #1 and #2, respectively; C13 are from terminal Funnel #13 (two trenches), C22_M1 is from a charcoal found adhering to a meteorite fragment found about 200 m to the NE from Crater#2 by Ranger Mariela Tessaro, (Inventory Province of Chaco:CH0487, Weight:0.23kg) during our fieldwork. Please note that some of the samples were processed twice (marked with ' and HS^4 and a thin grey box), with slightly different chemical preparation to test the potential of sample contamination by caliche (in two cases, they yielded the same ages; in one (C2_T2_61') the difference in resulting age was significant). From the samples selected for the ^{14}C dating, some were chosen to indicate the age of paleosol (marked as PS), and some were taken from the assumed ejecta layer (EJ). The origin of other samples was not certain. The numbers next to the layers correspond to the depth of the sample origin below the current surface. Grey rectangles show ages proposed by [5]. Our best guess of the CdC age is indicated with a green rectangle. Ages used for combined age are marked with green frames.

Results and discussion: A preliminary analysis (Fig. 3) of the data suggests that relying solely on three 14C dates to determine the age of the Holocene impact crater may carry some risks. Our best estimate for the CdC age is at a 95.4% probability: 1540-1410 cal BP (1619±14 ^{14}C yr BP). This determination combines five charcoal samples collected within the ejecta layer at depths >50 cm from two trenches within Crater #2 and a single charcoal next to the meteorite found 200 m to the NE from Crater #2. Remarkably, charcoal from the ejecta layer of Crater #1 exhibits a very similar age. The revised age is >2000 years younger than the previous determination of 4800-4090 cal BP (3945±85 ^{14}C yr BP) by [5].

Additionally, since we are suspicious people, we are concurrently working on OSL dating of a vertically arranged group of samples collected from the southern trench of crater #2 to hopefully investigate the age of the CdC event with an independent method.

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