ASTROBLEMES: THE RATE OF DISCOVERY, SPACE-TIME DISTRIBUTION AND AN EXAMPLE OF THE SIGNIFICANCE FOR ARCHAEOLOGY. A.A.Valter, Institute of Applied Phys. Acad. of Sci. of Ukraine. Malyshko str., 3, apt.449, Kiev-02192, Ukrain; avalter@iop.kiev.ua

About 46 years ago R.Dietz coined a new, somewhat poetical term 'astrobleme" (star wound). As the conditions on the Earth surface cause the craters to lose soon their original form, this name seems quite appropriate for the Earth impact structures. In accordance with the semantics of the word it can be applied to every kind of cosmic projectile impact on the Earth surface.

The investigation of astroblemes is important from the standpoint of acquiring new data on regional and global geological history, better understanding of the nature of the shock wave action on various natural materials as well as estimation of the meteorite flux onto the Earth.

The investigation of an astrobleme starts with its discovery. In [1] it was shown that at that time the number of astroblemes discovered grew as $N = e^{2,83+0,12t}$ ………(1) where N is the number of astroblemes found, t is the time in years since 1960, when the shock metamorphic features of minerals were acknowledged as the evidence of shock-meteoritic origin.

This rate of discovering astroblemes could not be maintained for very long. One can see in fig.1 that since ~ 1990 it has been on the obvious decline.

As long as the rate of the astroblemes discovery is higher than the rate of their formation, the relation (1) takes the form

$N_{dis} = N_{hole} - B\ exp^{at}$ ………(2),

where N_{dis} is the number of astroblemes discovered; N_{hole} is the total number of astroblemes whose traces can be found; B and a are the coefficients.

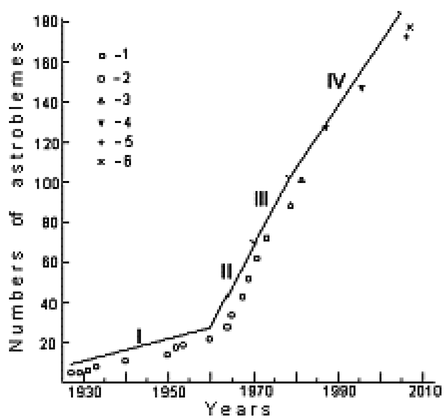

Fig.1.The dynamics of discovery of astroblemes and meteoritic craters.
1 – by B.French,1964; 2 –R.M.Millman, 19716]; 3–Valter and Riabenko,1977; 4 –V.I.Feldman, 1987,1993; 5 –Earth Impact Database, University of New Brunswick, Canada, 2008; 6 - S.A.Vishnevsky,2008.
I –early period before the discovery of shock metamorphic features; **II** – growth, mainly by Canadian shield astroblemes (P.B.Robertson, R.A.F.Grieve at al).; **III** – growth, mainly by the astroblemes of USSR (V.L.Masaitis et al); **IV** – growth, mainly by the astroblemes of North Europe, Africa, Australia and South America.

By our estimation, the most probable number of known astroblemes on the Earth is now 178. The small craters in the groups were not considered individually; only the dimensions of the largest one were indicated. The initial distribution of the meteoritic craters satisfies the relation $N_D = N_{Do} \times D^{-h}$(3) where N_{Do} and N_D are the numbers of craters with diameters D_o and D, respectively, ($D > D_o$). The value of h varies, as reported by different authors, in the range 2,05÷2,4. Probably, 2.3 would be the best[2,3].

The number of astroblemes formed on the Earth surface during the geological history ($\sim 3,6 \cdot 10^9$ years) cannot be determined with sufficient accuracy.

Using earlier estimates [2] of the quantity of astroblemes formed during the last 500 million years on plain dry land, and extending this data to the whole dry land area and entire geological history, one can obtain $6.5 \cdot 10^5$ for craters with D>1 km and $1.7 \cdot 10^7$ for craters with D>100 m.

More or less reliable estimates of the reserve of astroblemes to be discovered are only possible for some stable regions on the Earth surface.

The successful discovery of astroblemes also depends on whether the regions of interest are well studied, i.e.on the causes of social nature. The number of astroblemes is related to the preserved condition of relatively small and young structures.

Out of 178 astroblemes included in this paper, 128 are of Cenozoic age (less than 65 million years) (fig.2), of which 35 ages are less than 1 million years (table 1).

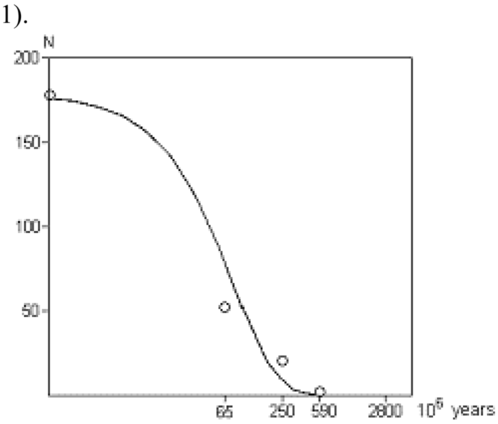

Fig.2. The integral curve of the age distribution for the known astroblemes. Ordinate: cumulative number of astroblemes; abscissa: astrobleme age; circles: data recalculated from [6] and corrected.

The curve in fig.2 can be described by the equation

$y=178\exp(-0{,}013t)$(4),

where y is the number of astroblemes of age older than t (in millions of years). This shape of curve (4) is mainly determined by the progressive destruction of small astroblemes with time.

Table 1

Age and size distributions for astroblemes younger than 1 million years (according to [4, 5] with minor corrections)

Age, years	The number	Min. diameter	Max. diameter
$20 \div 10^{4}$	10	10m Sterlytamak	300 m Macha
$10^{4}\div10^{5}$	19	157 m Henbury	1,8км Lonar 1x4,5км Rio de Cuarto
$10^{5}\div10^{6}$	7	24m Dalgaranga	14км Zamanshin

From Table1 one can see a log-exponential decrease in number of the preserved astroblemes with time and linear dependence of the maximum diameter on the age.

The average density of the known astroblemes on continents is (km-2): Africa – $6.5\cdot10^{-7}$; Asia-$3.5\cdot10^{-7}$; Australia-$3.4\cdot10^{-6}$; North America-2.3·10-^{6}; South America-$4{,}4\cdot10^{-7}$; Europe-$5{,}3\cdot10^{-6}$. This difference could be due to the differing depth of the geological studies. Thus, the astroblemes density for the best studied continents is $3{,}25\cdot10^{-6}$км$^{-2}$ while for those worst studied is $4{,}6\cdot10^{-7}$, and the reserve of astroblemes which are relatively easy to discover can be roughly estimated as ~ 290.

As regards the smallest and the youngest astroblemes, the desire to search for them is a major impetus to their discovery. The highest density of small astroblemes among countries is found in Estonia ($1.3 \cdot10^{-4}$ km^{-2}), which is apparently due to a great interest in meteorite craters in this country. This value is close to the astronomical estimates [3 , 4] for small meteorite craters (30 – 100 m) formed on the Earth surface during the last 50 thousand years.

So, the reserve of small craters which are easy to discover can be estimated as $N>10^{3}$.

The Ilintsy astrobleme in Ukraine is a good example to illustrate the significance of such structures for archaeology. Since the 3-d century AD, for about one thousand years, suevites from Illintsy outcrops have been worked out for producing hand millstones. . Because of the unique nature of this material it was possible to determine the areas of raw-materials and products spreading and thus, the commercial connections in Ukraine at that time [7]. In ancient drops we found a product from deer horn (fig.3) which was very much like similar artefacts digged out in old Russian town of Voin (X1-XIII Century AD) – now under water level in the mouth of Sula river.

Fig.3. The product from the deer bone found in the ancient drop of the Illintsi suevite output

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