HERTZIAN FRACTURES

And Related Terms – a Glossary

by James Byous

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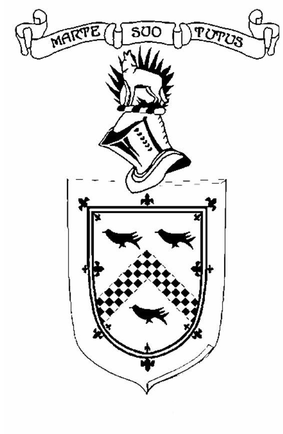

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Hertzian Fractures and Related Terms - A Glossary

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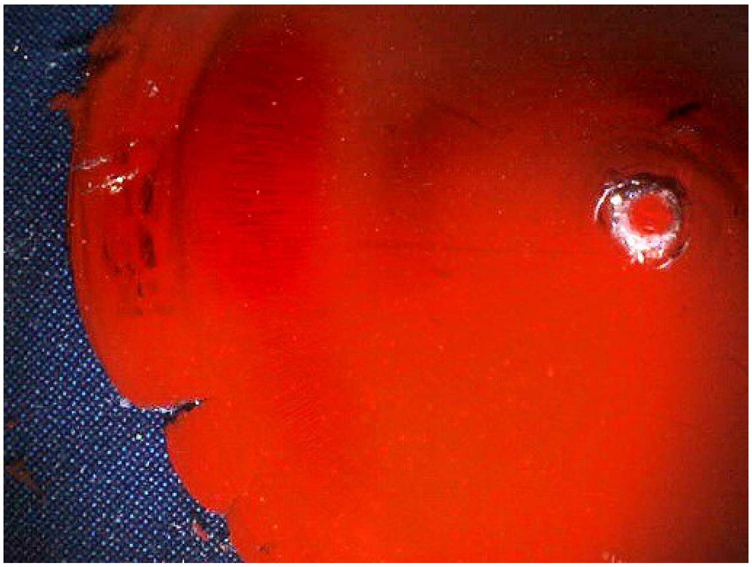


Figure 1 *Above, a stained Hertzian fracture mold exhibits (from left) flange and lobes, hackles (indistinct), terrace, crater and Wallner lines. All are within a radius of about 12mm.*

Introduction

From the time the first hand-scratched artwork appeared on a cave wall Hertzian fractures have held a partnership with mankind. Lithic blades and points used these features of physics to sharpen tools for chores in family life, in hunting and in times of war. Generally called choncoidal fractures in archaeological circles today, early man knapped segment after segment to create razor-sharp biface arrowheads, scrapers and other tools.

Hertzian fractures have been studied extensively to determine the results of their creation. Forensic experts study ballistic processes at crime scenes. The armor industry calculates the reactions of materials during their formation. NASA studies their creation in windshields on spacecraft to protect those who float among the stars. And, Hertzian fractures are responsible for our ability to obtain the oil that we use to power our world since they are the cutting force created by drill bits deep below the surface of the Earth. They can be a friend to mankind or an enemy -- if it is possible for an inanimate object to be either. Yet little has been published listing the nomenclature for constitution, physicalities and processes that form on and around these Hertzian features; mega, macro, micro.

This glossary is an attempt to collect data from varied industries, fields and disciplines to provide a starting point for a cross reference of information. Many terms and elements are still hypothetical, but logic suggests that physics will agree with these conclusions in further tests. Additions and suggestions are encouraged. Feedback and input are invited. Please send comments and information to byous@dowdresearch.org.

Gratitude is expressed to all listed herein for their work and their cooperation. This publication is for research and educational purposes only. Please do not use any part, written or illustrated without permission from copyright holders.

Glossary

Alcove A fracture or void in the outer wall of impacted target material perpendicular to the plane of impact creating a circular or semi-circular feature or inset. An alcove is considered a circular or semi-circular anomaly (CSA.) (Appendix 3, Figure 42.)

Amorphous Being non-crystalline without definite structural parts with molecules arranged randomly like those in a liquid.

Angle of Attack (AAT) The angle of the path of the projectile from true horizontal along the plane from 270 degrees to 90 degrees. True vertical is 0/360 degrees.

Appendage Cone (*Figure 2)* A partially attached Hertzian cone that is connected to a section of overburden but free from eroded or removed sections of the target material.

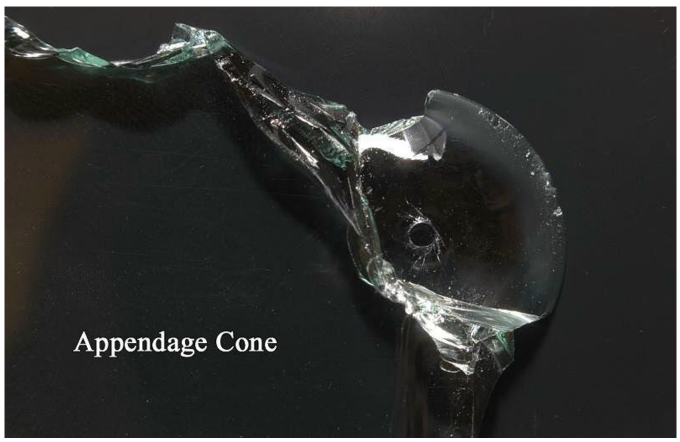


Figure 2 *Appendage Cones are attached to overburden.*

Backspin Annular rotation of a projectile on the X-axis counter to the direction of travel. The projectile can deviate upward along the path creating a "U" shaped arc. It can also create back pressure on the target tilting the Hertzian cone (HC) away from the point of origin. With backspin the projectile "digs" into the target the way a golfer uses backspin to hold the ball on the green after a chip shot.

Blast Arc/EnergyArc (*Figure 3*) The arced segment of a blast or energy release that can be seen on the ground at blast sites or in the features of some Hertzian cones. The structurecan resemble a starburst or ray flower petals in the lamina arrangement.

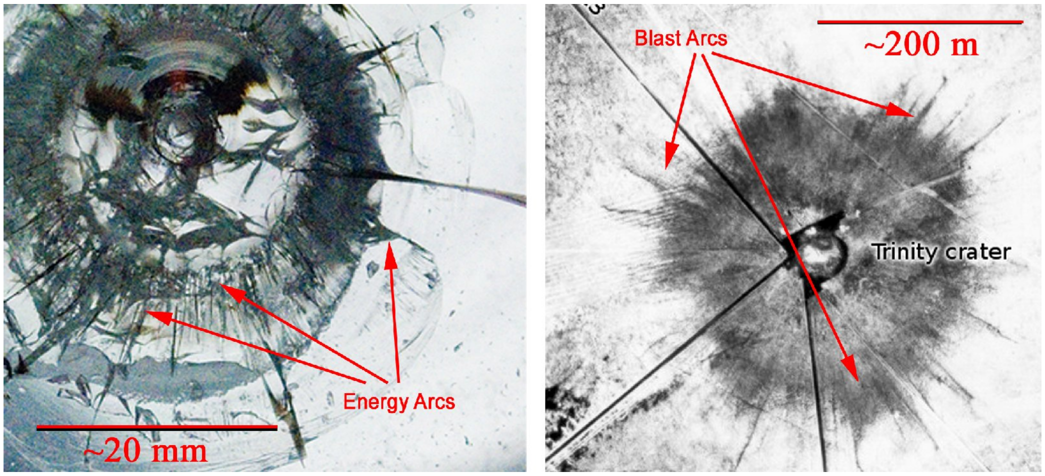


Figure 3 *Energy dispersal patterns in HC, left, and nuclear blast, right.*

Blast Cells/Compression Cells (*Figure 3 & 4)* Circular or ray-like segments displayed in energy release. These are found on images of early above-ground nuclear explosions and appear as energy circs (CSA) on many Hertzian fractures.

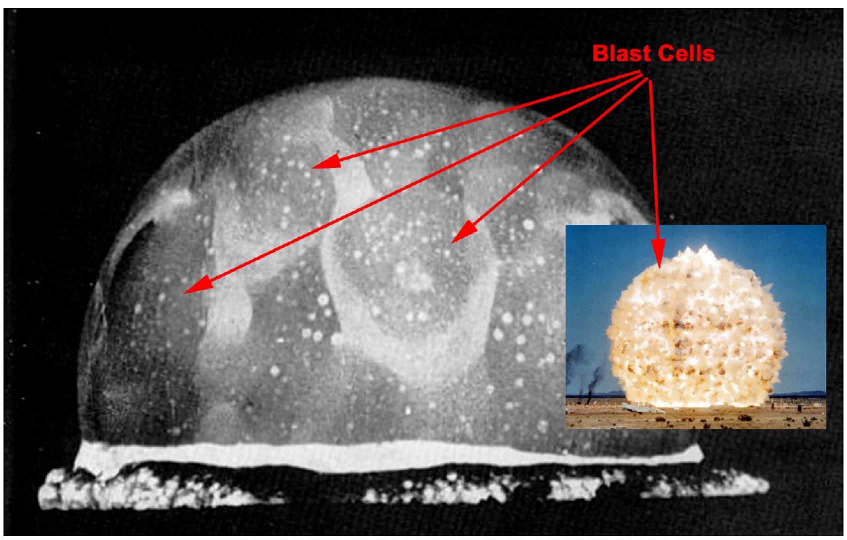


Figure 4 *Blast cells in nuclear blast.*

Bolide Any large crater-forming impacting body, a meteor or comet. It can be a rock or metallic asteroid, an ice comet, a combination of all three or a fireball. The term is generic since there is no consensus among fields as to a single definition.

Chatter Marks *Figure 8* Hertzian fractures in succession along a brittle material caused by an indenter. They are commonly found in ceramics, glass or rock. Glaciers form chatter marks when boulders are pulled across smooth outcrops. Also "chattermarks."

Circular and Semi-circular Anomalies (CSA) *Figure 5* Circular patterns that are created by wave deflection around a heterogeneity or void in target materials. With heterogeneities, a Hertzian cone's circ is seen as an anomaly in the surface material. It can manifest as a fracture, discoloration due to intrusive materials, changes in surface structure and elevation and in other forms. The acronym CSA can be used as a singular or plural reference, however, it is also correct to write CSA's for plural. Also, Energy Circs, or in craters, Compression Cells.

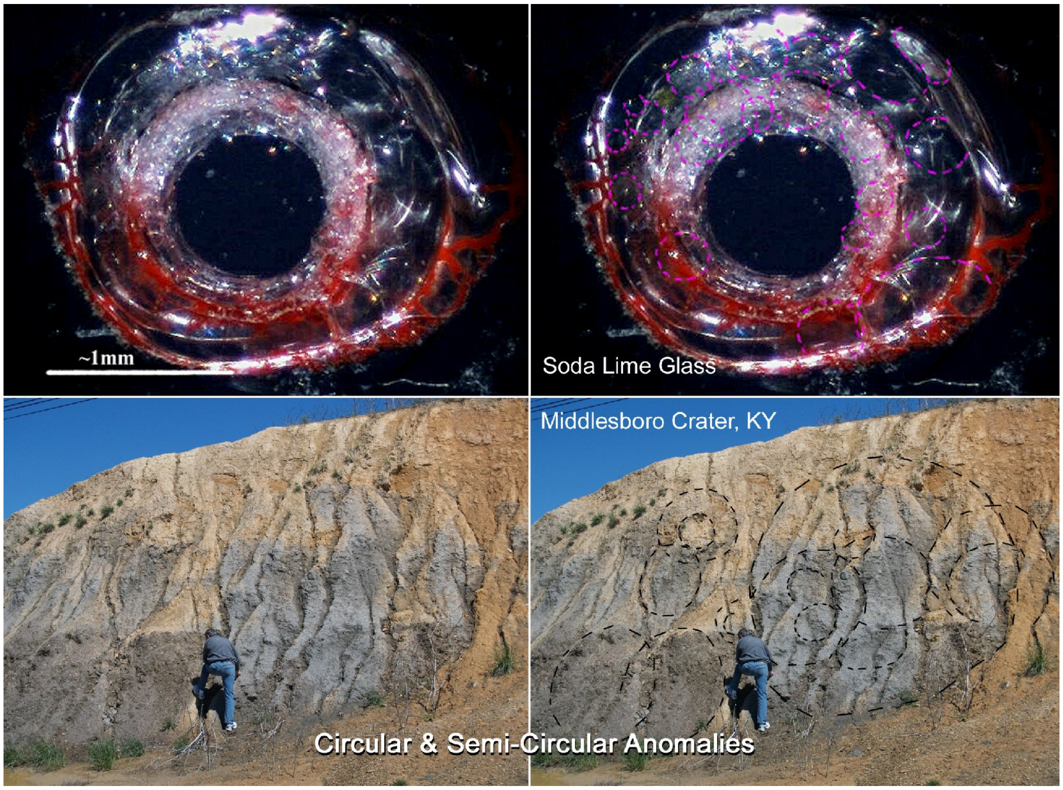


Figure 5 *Top, circular and semi-circular anomalies in a crater in dyed soda lime glass. Bottom, arcs in an excavated berm in Middlesboro Crater, KY where semi-circles, and a few complete circles erode due to microfractures.*

Clingy Odd diversion or rotation of a projectile and subsequent anomalous result in impact patterning.

Coincidal Impact Multiple projectile impacts created at the same time or within a near instantaneous time.

Comminution The process in which solid materials are reduced in size by crushing, grinding and other processes.

Comminuted/Mescall Zone Figure 6 The area beneath a crater that has been highly crushed and fragmented.

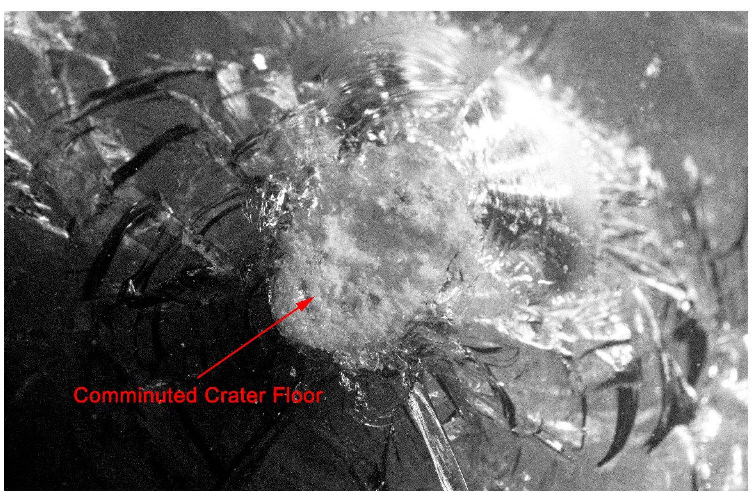


Figure 6 *Comminuted, crushed material in a soda-lime glass crater.*

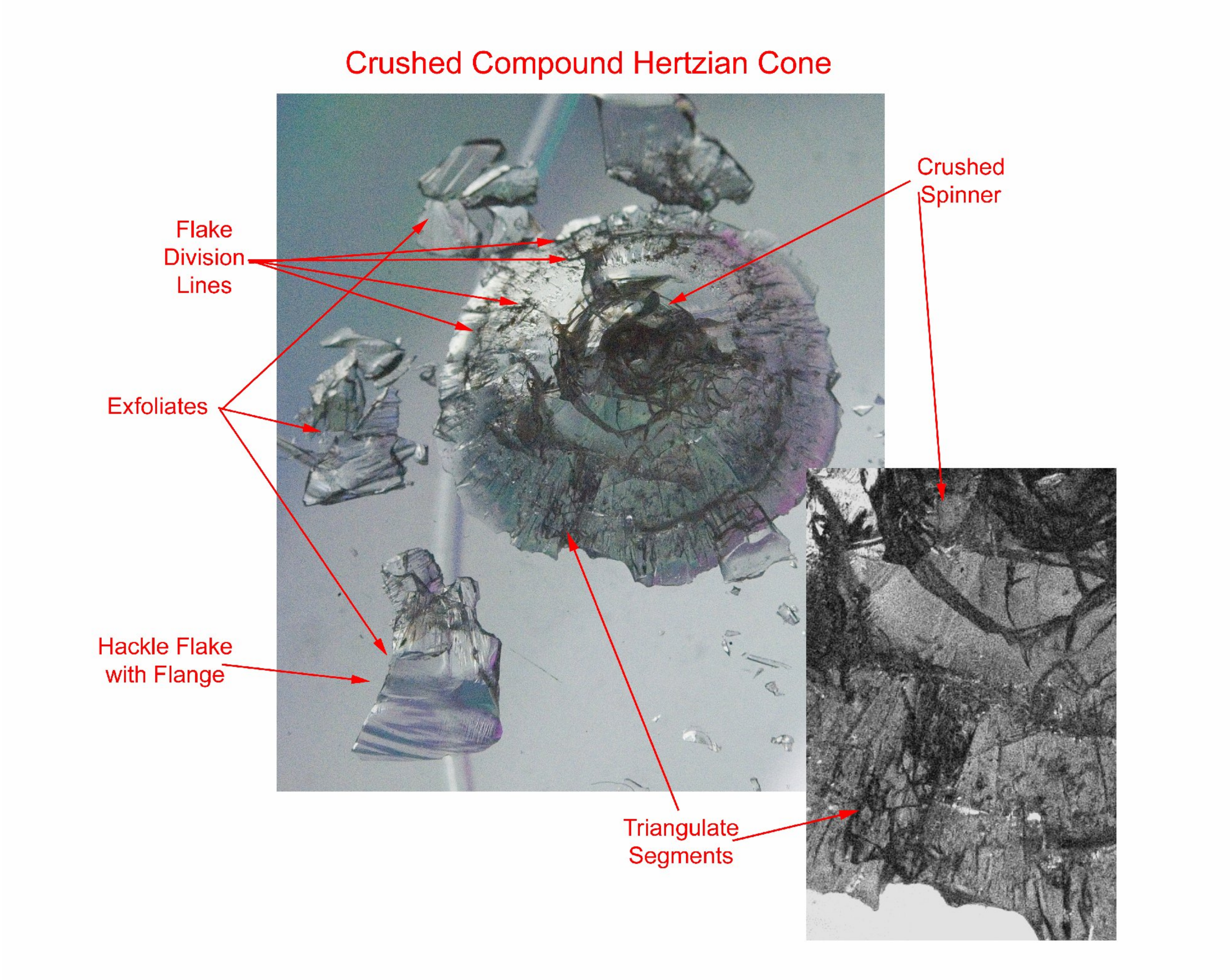


Figure 7 *A crushed compound Hertzian cone segments under polarized light. Triangulate segments are seen at right.*

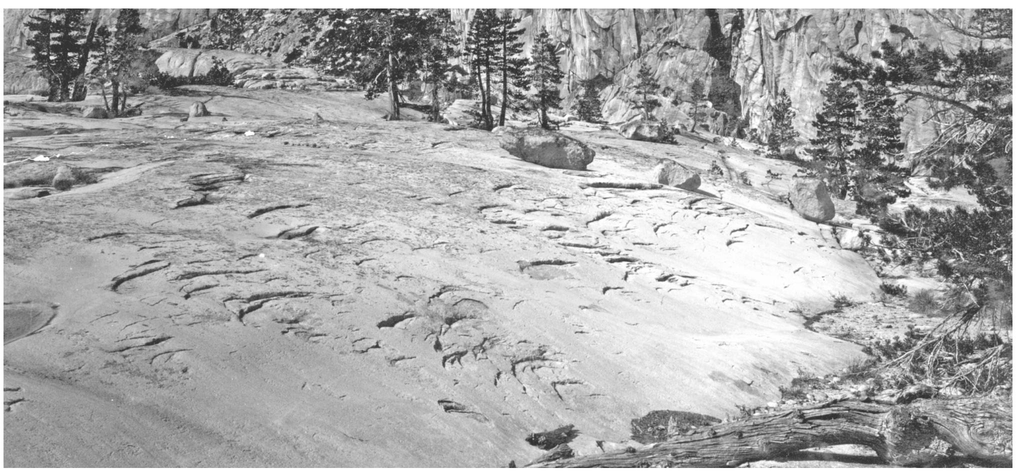


Figure 8 *Glacial striae and chatter marks in Yosemite National Park. Glacial ice moved from left to right dragging boulders across the granite plane.* *Photo: G.K. Gilbert USGS 1903.*

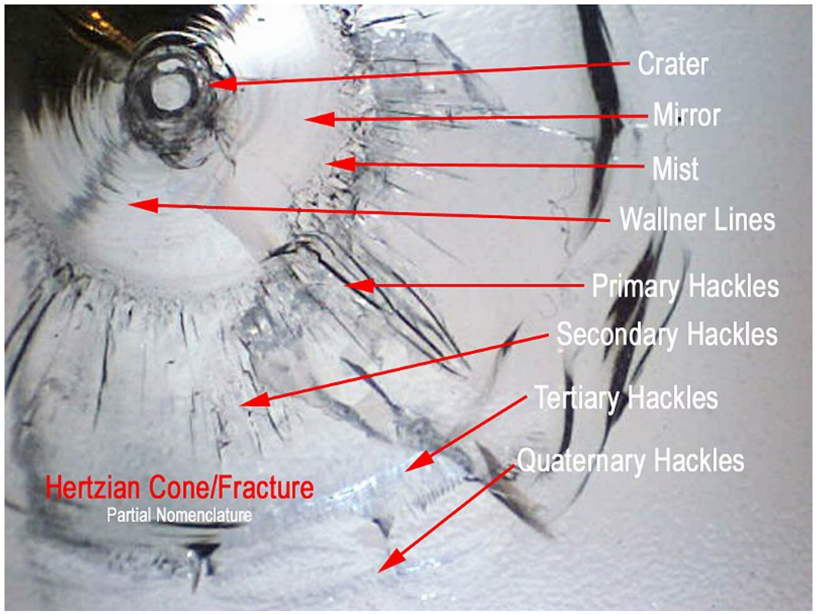


Figure 9 *Sequential divisions in a compound Hertzian cone.*

Compound HC (Figure 9) A Hertzian cone containing elements beyond the basic features, point of impact, mirror, mist, hackles and Wallner lines. Compound HC's can include multiple lines of any of the previous and… may also include partial or totally crushed segment. It may also include pedestals, laminae, lobed or flanged hackles, triangulate segments, facetal fractures and other features.

Compaction Wave/Rarefaction Wave A third wave released during impact following P- and S-waves. P-waves are pressure waves that promote elastic and plastic deformation. They are the resultant effect as the kinetic energy transfers from the projectile to the target material. P-waves move at the speed of sound in the target material and can also be elastic or plastic. However, in glass compaction-wave's maximum speed cannot exceed that of the projectile. *Also: Transfer wave, created when projectile inertia transfers to the target material.*

Compression A reduction of molecular volume through inertia. It can be temporary when within the elastic limits of the material or permanent as plastic compression waves pass through.

Compression Cell CSA features within a crater including floor, wall and rim sections.

Concentric Crack Fractures forming in an annular pattern around a principal point. In Hertzian fractures, cracks that form around the point of impact or other points of stress.

Conchoidal Fracture Term generally used in reference to flutes in lithic tools and weapons. Also Hertzian fracture.

Cone Sequence The sequence of features on a Hertzian cone from the crater outward. The sequence in *Figure 7* is: Crater, mirror with Wallner lines, mist, Primary Hackle, mirror 2, secondary hackle, mirror 3, tertiary hackle, and flange with quaternary hackle. See Compound HC.

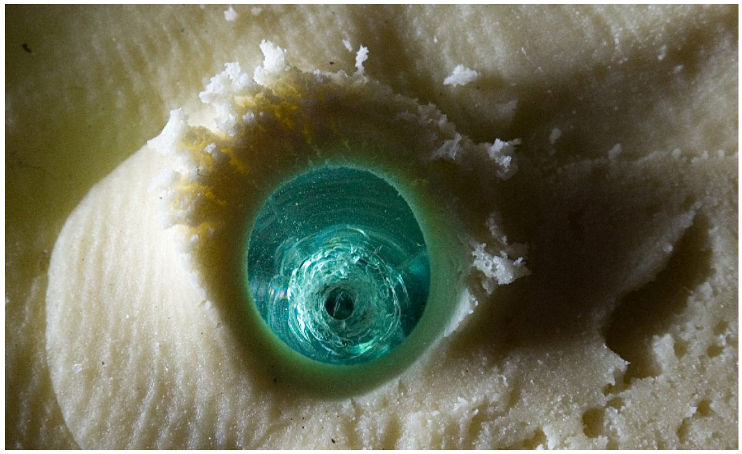


Figure 10 *A crater and sub-surface Hertzian cone. A combination of 5mm soda lime glass and a "crustal" coating of modeling clay. The crater was made by a 5mm steel projectile.*

Crater Figures 10 & 11 The hollow or scar created by a projectile or indenter in the upper surface of the target material. It includes the point of impact, crater wall, crater floor and can include crushed or folded target material around the area.

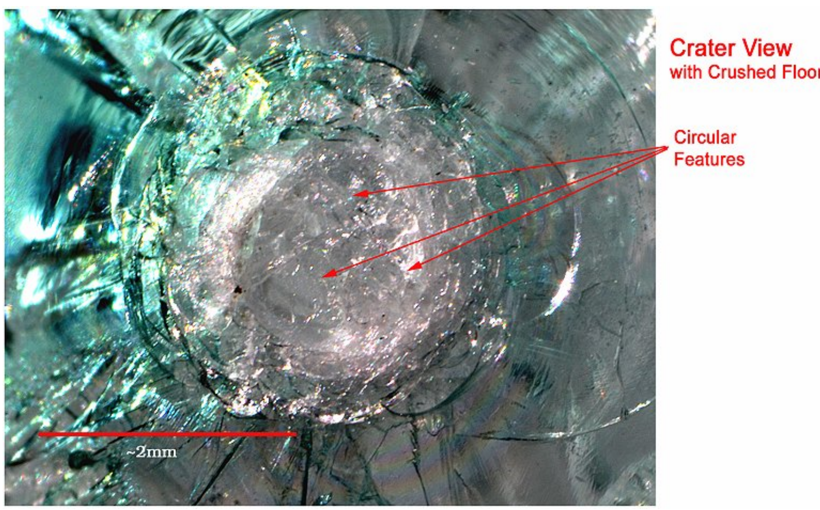


Figure 11 *Crater in soda lime glass with CSA features (Compression Cells).*

Crawl/Curve Deviation caused by english from the initial direction of travel due to spin or ration around the Y-axis' planar-rotation along the projectile path. A horizontal rotation can facilitate a curved path in a projectile in the same manner a baseball pitcher throws a curve ball. In air guns the ball projectile can "hug" the side of the tube or barrel to cause varied rotational patterns.

Critical Flaw The area at the base of the crater where the annular fracture initiates to create separation between the overburden and the HC. It may initiate in the wall of the crater below the crater floor. Same as Inertia Transfer Line.

CSA A circular and/or semi-circular anomaly in crystalline materials**.**

Deflection Redirected energy waves reflected from or around a heterogeneous solid or void in the target material.

Direction of Projectile (DoP) The direction is indicated by compass bearing from point of origin to point of impact when available. For simple computations the point of impact (POI) being the balance point of the compass. For vertical targets 0/360 degrees north is always upward opposite the direction of gravitational pull. For flat-surface, horizontal impacts true north is used, An impact on a flat surface is recorded by the direction and the attack angle of the projectile in two directions. In zero gravity environs the appropriate gravitational direction, Earth, Sun, Moon, Mars or a determined feature is used as the locator. DoP/45dE/80dS = Projectile path 45 degrees east by 80 degrees south. Forensic ballistic sampling uses degrees from impacted surface to find the path of the bullet. Also Projectile Trajectory.

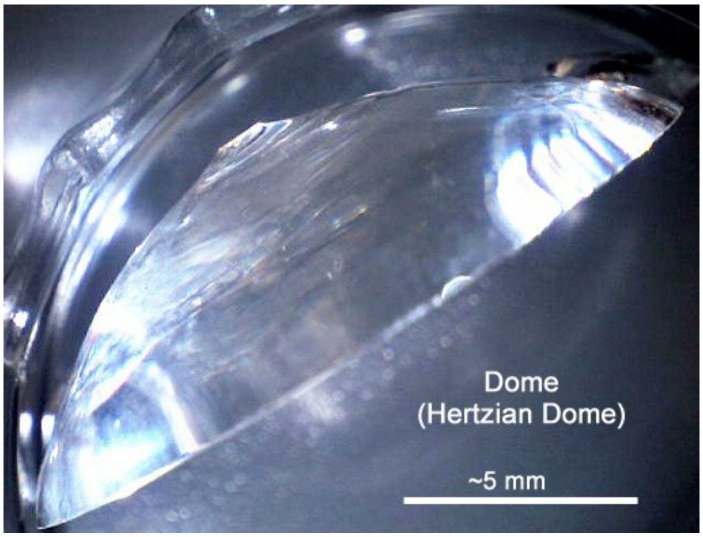


Figure 12 *A simple domed HC with pedestal in profile.*

Dome Figure 12 A complete transitionally curved Hertzian cone with or without connected laminae.

Dome Core Figure 13 The central section of a Hertzian cone with detached laminae.

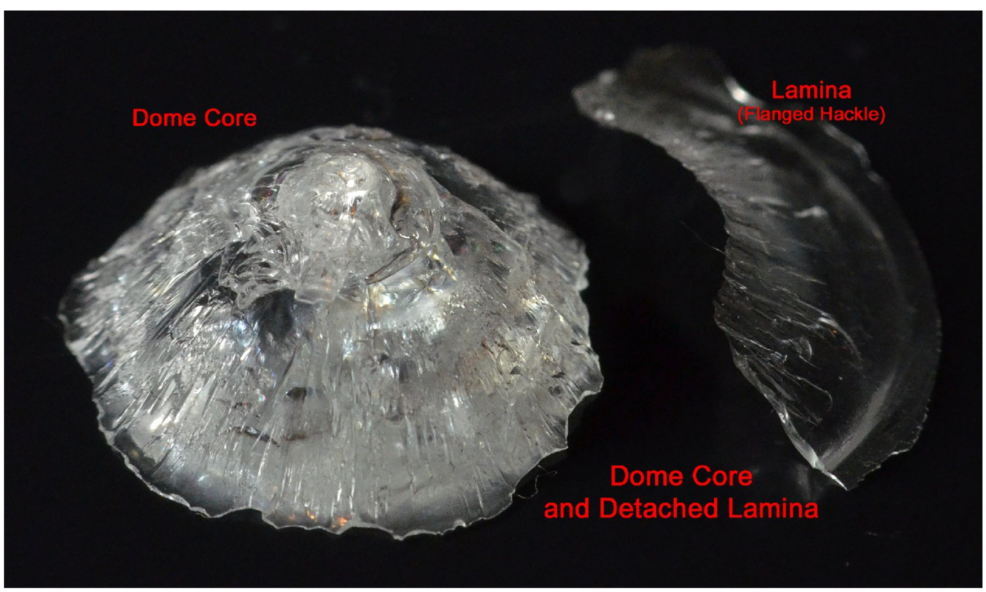


Figure 13 *A domed HC core with detached flanged lamina.*

Ductility (Figure 30) A mechanical property in that it is a point where the extent of a material can plastically deform without fracture. A material's ability to deform under tensile stress without fracture.

Elastic The property of a material that returns it to its original form after the removal of a deforming force. See Plastic

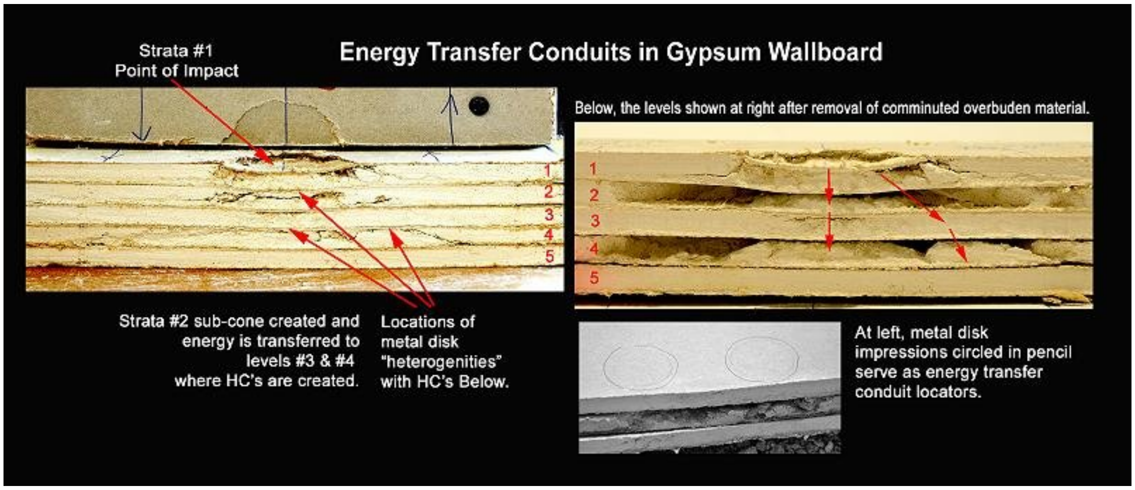


Figure 14 *Energy conduits create sequential HC's through heterogeneities in gypsum board.*

Energy Transfer Conduit (ETC) (Figure 14) The location within a target material for transfer of energy from one stratum to another or one level to another. ETC's are created when impact energy compresses target material below heterogeneities in successive strata creating sequential Hertzian fractures. Shatter cones are examples of impact generated ETC's but in addition display sloped, hackle-like striations from apex to base.

Energy Circ (CSA) (Figure 15) Circular feature found in impact material similar to a shatter cone but without feather or horse-tail features. They are usually very faint and are created when compressive waves divert around heterogenic locations or voids creating a wake of disturbed, fractured or altered target material. Same as Heterogenic Circ.

Figure 15 *CSA's in embankment Faith Missionary Baptist Church property, Middlesboro Crater, KY.*

Energy Channel (EC) (Figure 16) Areas of a compressed, but unfragmented segments bounded by fractures in a Hertzian cone through which energy has traveled through or around from the Point of Impact to the base or to lower strata. EC may spiral or bend in their route forming a "frozen waterfall" visual when separated from the HC. A lamina is a form of energy channel on the outer bounds of a Hertzian cone.

English The spin on a projectile that creates torque in the point of impact likened to English sidespin used in billiards. Though the billiard term denotes sidespin only, projectile impact may denote any direction of rotation or spin.

Facetal Fractures Cracks along face of HC at random or including the divisor area between hackles, lobes and laminae.

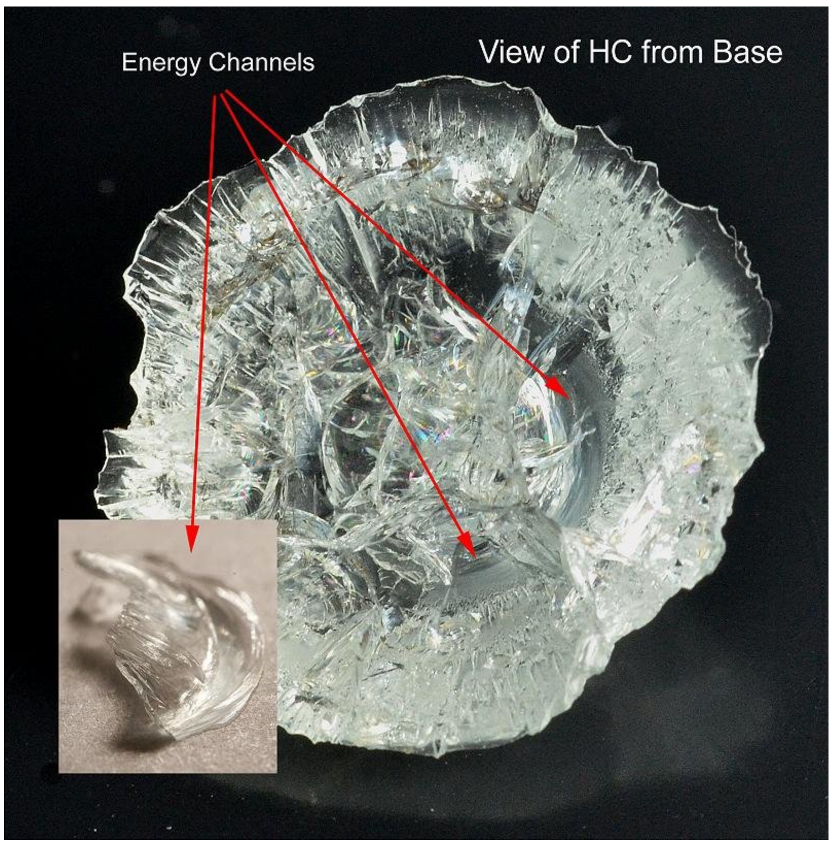


Figure 16 *Clear energy channels are visible through the base of this HC. Energy flows through EC's compressing the target material while fracturing material between.*

Failure Boundary The point of compressional force or a physical location at which target material fragments in a Hertzian cone, i.e. Failure boundary was reached at 2Gpa or fragmentation occurred 2.5mm below the surface.

Failure Wave The wave along which a Hertzian cone fragments into what has been described as a three dimensional jig-saw puzzle. Components are held in place if overburden is not destroyed by the impact.

Feather Hackles (Figure 15) Very fine plume-like, "feathered" hackles that can be found throughout HC's and fractures but are most often found around the crater area. Also Plumose Hackles.

Feathered Lobe or Flange (Figure 18) Feather Hackles on the base extremes of HC's. Many times they show up as tertiary or quaternary hackles.

Flake (Figure 8) A detached hackle. A piece of target material fractured from a larger material by the application external or internal force. A segment of core material from around the extremity of a Hertzian cone that falls away like the layers of an onion. Micro and macro flakes are found in Hertzian fractures. Mega flakes are found in granite mountain domes.

Flange (Figures 8 & 18) An external rib of Hertzian cones and fractures that deviates from the mean angle and are sometimes found at the base. The flange demonstrates P-wave rebound from a strata or base plane, "hammering" the annular fracture outward into a thinned layer.

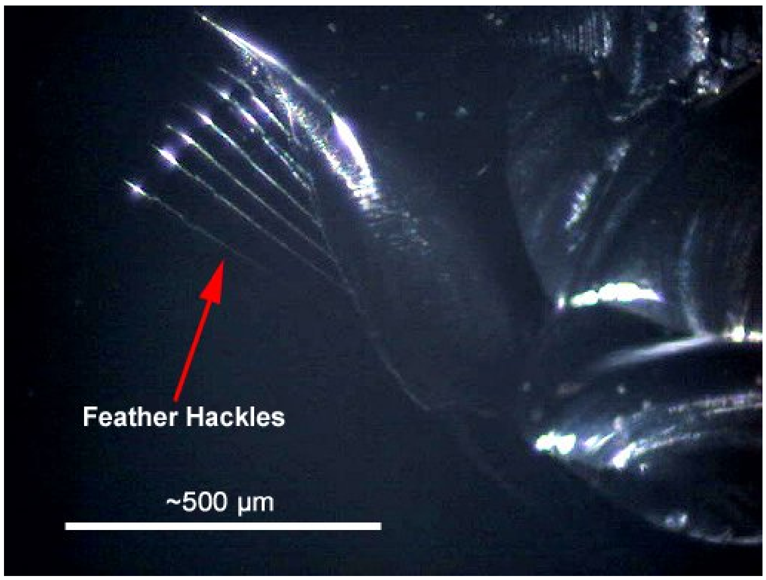


Figure 17 *Feather hackles near the separation point, floor follow, of the crater seen in Figure 19. Feather hackles are found throughout HC's.*

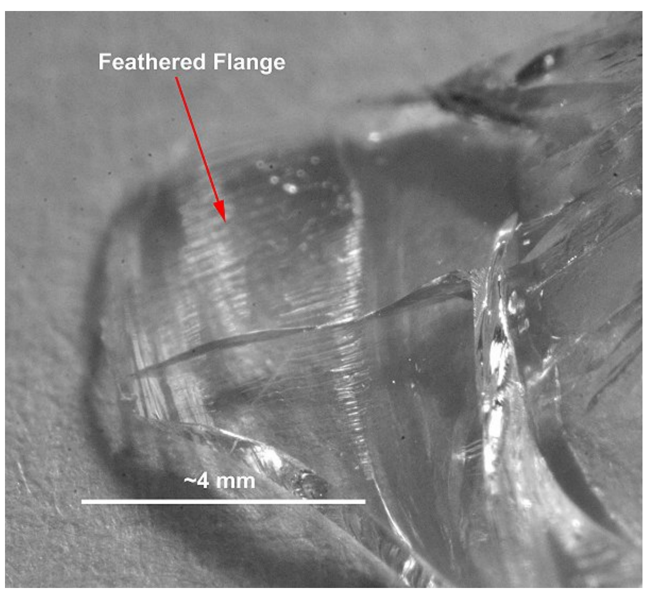


Figure 18 *A lobed flange with feather hackles.*

Floor follow (Figure 19) The process in which the crater floor stays in the crater after the Hertzian cone has separated from the mold.

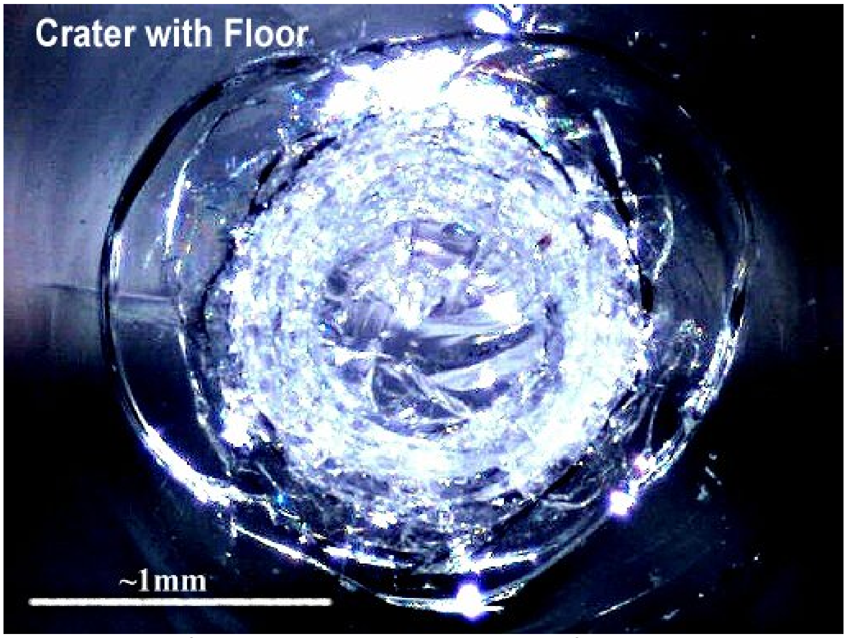


Figure 19 A crater floor that remained in the crater as part of the overburden. Floor follow is the result when the cone was removed as in Figure 17.

Flexural Strength The strength of a material to bend elastically.

Force Any external agent causing change in motion, stress or fracture in a target material. It has both direction and magnitude.

Fragmentation The crushing of the Hertzian cone by projectiles or indenters. In grinding or drilling of brittle materials it is when the process changes from slicing to fragmentation -- from elastic-plastic indentation to the creation of Hertzian fractures.

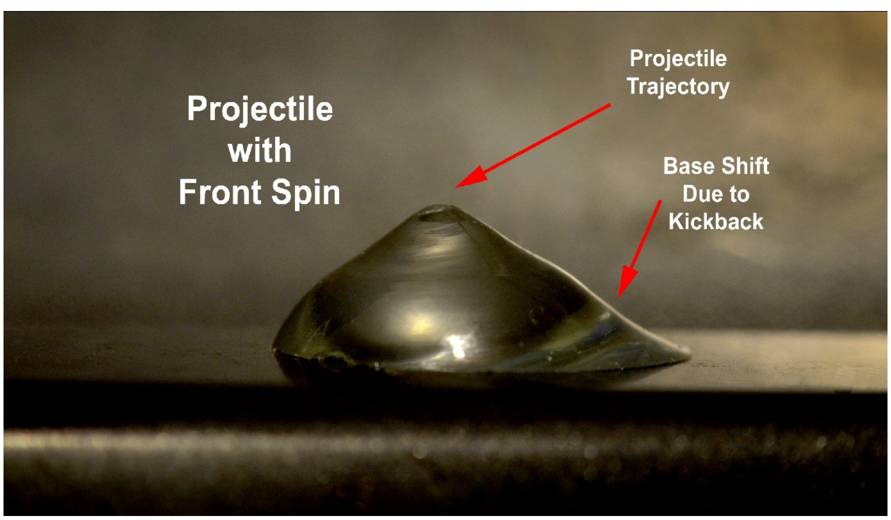


Figure 20 A Hertzian cone with base shifting due to a forward spinning projectile.

Front spin (Figure 20) Annular rotation with the top, Y-axis moving in the direction of travel faster than the speed of the projectile. Upon impact frontspin can create a cone with the base forming to the rear of the POI, spreading back from the point of impact. High speed rotation can create a Forward Jump sequence. Also, forward spin.

Forward Jump (FJ) A general term for forward co-directional rotation causing multiple points of impact, i.e., skipping or bouncing, from a single projectile. Also, front jump. See Scott's Jump.

Hackles (Figure 21) A common hackle is a linear feature on the surface of a HC, running radially toward the base. They can include starburst-like rays or platelets along the slope of Hertzian molds and Hertzian cones. In compound HC's primary, secondary and tertiary hackles may form. Facetal fractures form the boundaries between lamina hackles and can be found along the run of the base including flange and lobe sections.

Hammer Marks Lightly concaved or convexed circular or crescent shaped features that resemble depressions and ridges made by a hammer on metal or rock. Found in rocks at Middlesboro crater, Kentucky and in images of Apollo missions on the Moon. Individually they appear to be similar to shallow Hertzian fractures as are found in projectile studies. Their formation can be explained in softer material studies. Woodworking samples of hammer impressions in soft fiber woods illustrates the concaved features. Fiber erosion via hand sanding without a sanding block will produce a convexed bulge due to harder, compressed fibers. The latter are formed in the same manner as Hertzian fractures in crystalline materials when molecular volume is reduced during plastic deformation.

Heterogeneity Inconsistency in a material including areas of differing density or composition. *Antonym: Homogenous.*

Heterogenic Circ See Energy circ.

Hertzian Cone (HC) (Figure 22) The positive, dome shaped mass below the plane of the target. Overburden has been removed or has eroded to display the HC. Features include the body of the cone with point of impact (POI), pedestal, and occasionally the floor of the crater, along with mirror, mist, hackles and Wallner lines.

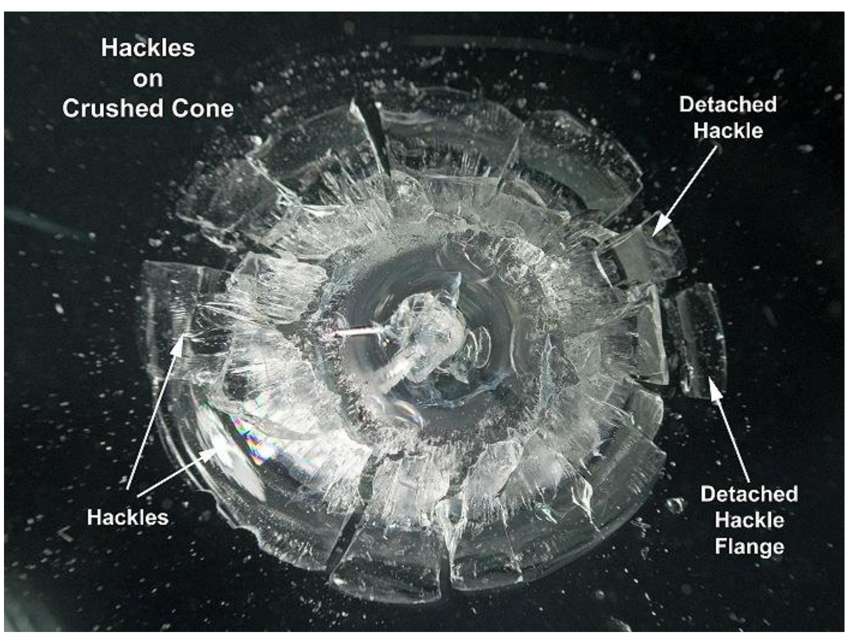


Figure 21 *View of a segmented, crushed Hertzian cone. Laminae may divide radially, annularly and internally.*

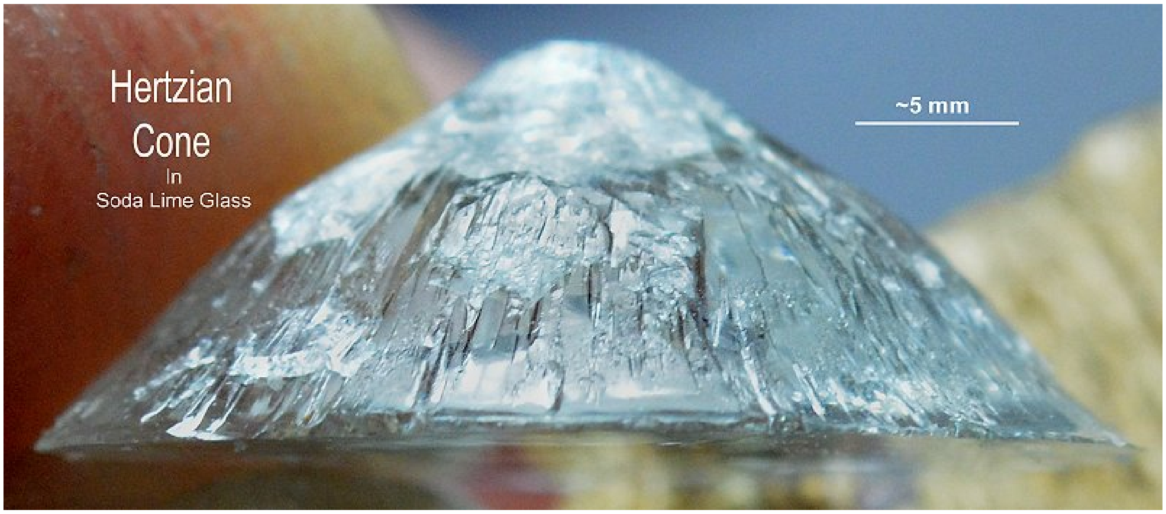


Figure 22 A 25mm diameter Hertzian cone replicates a mountain. The finger tip holding it can be seen in left background.

Hertzian Fracture/Hertzian Cone Fracture (HF/HCF) (Figure 23) The initial breakage and subsequent cone-shaped void between the Hertzian Fracture Mold and the Hertzian Cone while the two are still physically connected. The code HCF (Hertzian Cone Fracture) is used to indicate that the overburden is still in place. However, the term is often used to indicate either the Hertzian mold (negative) or the Hertzian cone (positive).

HCF's are also called conchoidal fractures in many disciples and fields using the term to indicate the Hertzian Fracture Mold. The term conchoidal fracture is primarily used in the archaeological field to indicate fluted voids on primitive stone and glass tools that create a cutting edge of arrowheads, blades, etc.

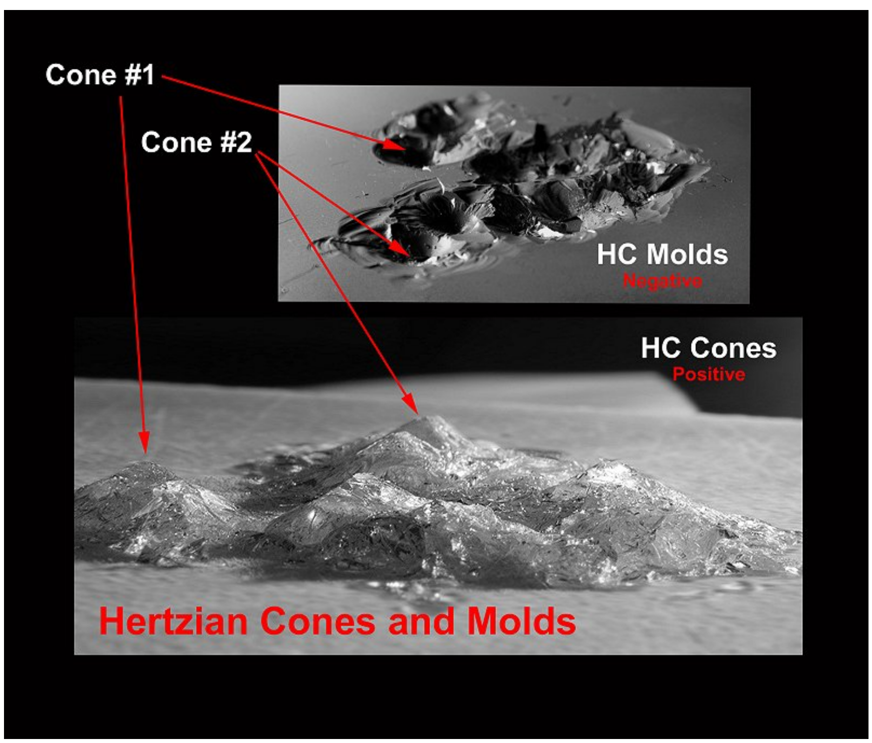


Figure 23 Hertzian cones, bottom, and the molds in overburden at top, seen upside down.

Hertzian Fracture Mold (HFM) (Figure 21) The negative, dome shaped area beneath the plane of the target material. Overburden is still in place or only partially removed or eroded. Segments include the crater, occasionally the crater floor, and the negative components of the mirror, mist, hackles and Wallner lines. In glass, ceramics and like-sized materials modeling clay can be pushed into the mold to create a positive form of the HC.

Hit A point of impact along the surface of the target. A crater is one form of a hit as is a simple scuff mark on a surface that does not fracture the target material.

Hit - Double/Multiple (Figure 24) Multiple points of impact or craters closely grouped regionally from single or multiple projectiles.

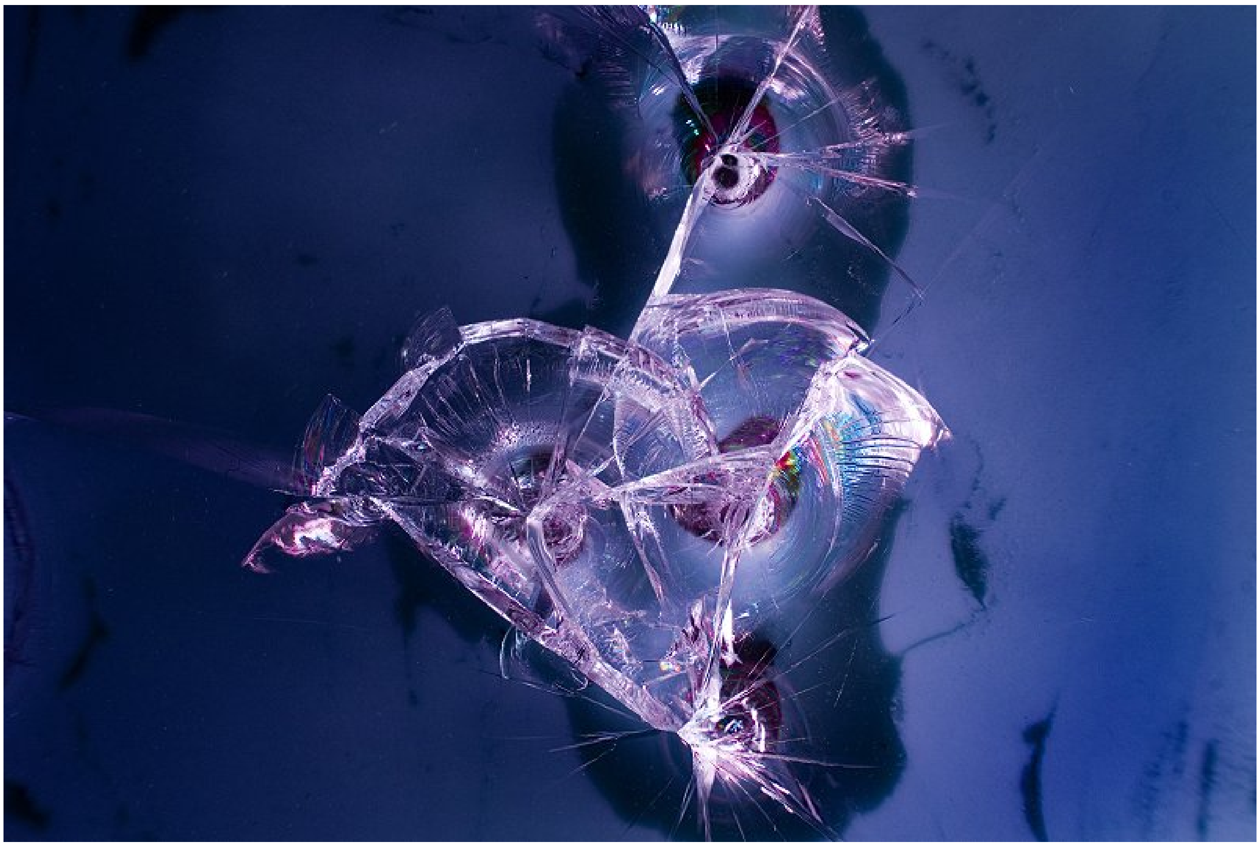


Figure 24 *Multiple hits in a sheet of soda lime glass from below. Cracks can indicate the sequence of impacts by studying the radial fractures. Later cracks generally do not cross the earlier fracture line.*

Horseshoe Crab Cracks (Figure 25) Tensional fractures around the point of impact and pedestal on a Hertzian cone with similar shape and features of a stylized horseshoe crab including tail and back shell configuration. These are formed by angle, direction and rotation of projectiles. The “tail” fracture indicates the origin of a slowly or non-rotating projectile and the opposite direction of rotation for backspin or sidespin projectiles.

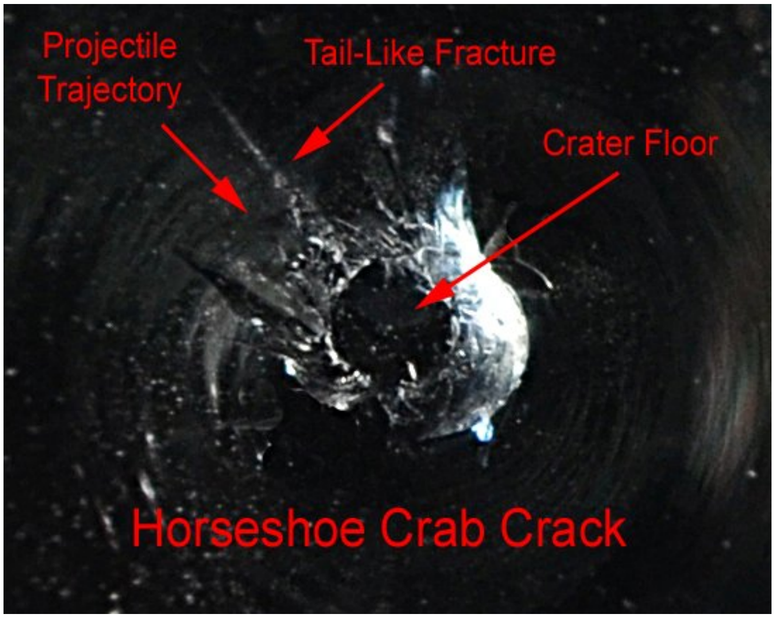


Figure 25 *Horseshoe Crab Cracks can indicate the trajectory of the Projectile.*

Impact Compression Factor Upon impact and creation of a Hertzian cone the molecules of the cone are elastically and plastically compressed in varying degrees. Density of the cone is greater than the overburden in surrounding material. Therefore, for normal erosion rates, the overburden material is reduced more rapidly that the material in the area of the cone. As an example, in woodworking, if a hammer blow creates a dent in wood the craftsman must use a sanding block to reduce the surrounding material evenly. The block forces level reduction in cone material and surrounding material. Without the sanding block the denser area of compression forces the sandpaper to override the cone material leaving a bulge in the surface while reducing the softer, surrounding fibers.

Inertia Energy An object's resistance to change in the state of its motion.

Inertial Compression Upon impact the stored energy of the projectile or indenter compresses the material in the cone. In glass panes the cone may be dislodged and be forced out of the plane opposite the point of impact.

Inertia Transfer Boundary The point where inertial energy is transferred from the projectile or indenter to the target material.

Inertia Transfer Line A delineation below or around a point of impact or crater floor where impact inertia creates the Hertzian fracture separating the H-mold and H-cone. Same as Critical Flaw

Kinetic Energy The energy possessed by a body in motion.

Laminae (Figure 26) Exfoliation flakes creating layers around the HC in an onion-skin like manner.

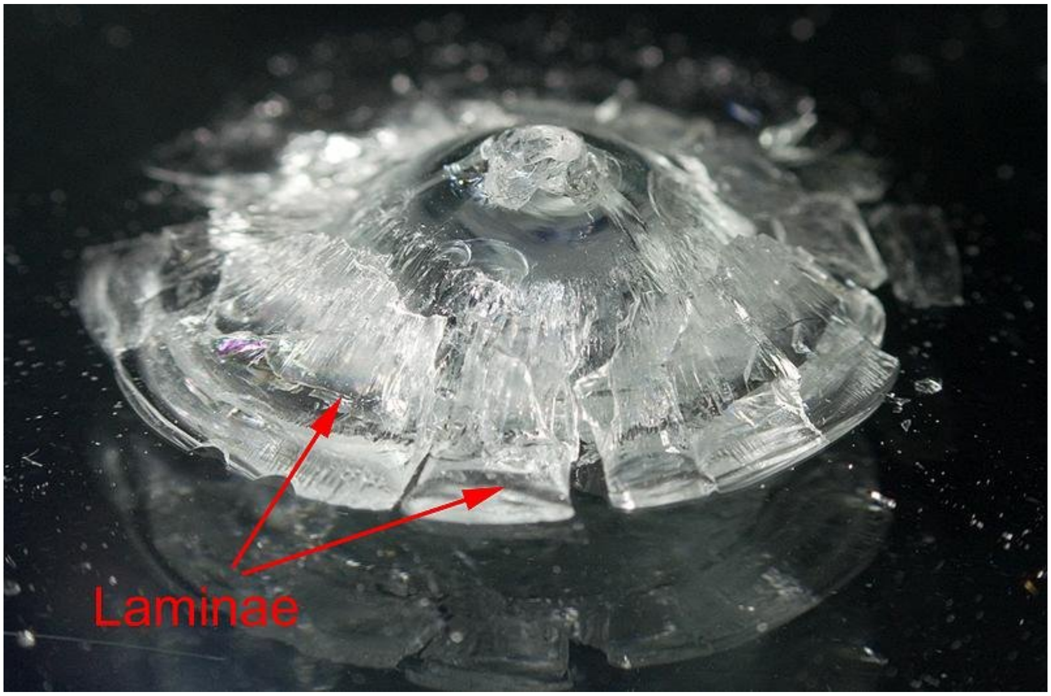


Figure 26 Detached laminae (flakes) with flanges. The Dome Core can be seen inside the outer band.

Lobe (Figure 18) A rounded appendage protruding from a Hertzian fracture or cone at the base. It is hypothesized that the lobe is formed when P-Waves bounce off of a hard stratum or in thin glass, the bottom plane of the sheet in eddy-like segments. Irregular distribution creates lobes and uniform distribution creates a flange. They may appear with or without an obvious flanged rib.

Lobed Flange (Figure 18) Outwardly, deeply-indented and rounded horizontal appendages along the external flange of Hertzian cones.

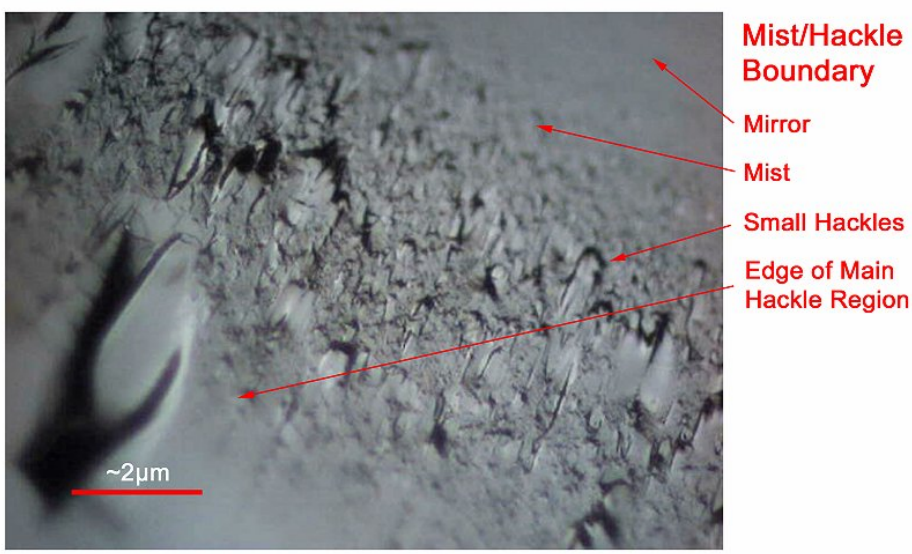


Figure 27 The Mist area of a Hertzian cone is the boundary between the Mirror and Hackle sections.

Mist (Figure 27) The point at which a Hertzian cone starts to, in essence, tear from the Hertzian Fracture Mold due to directional change in the annular fracture due to progressing projectile, indenter or explosive inertia.

Mirror (Figure 9) The generally smooth annular fracture, sometimes with Wallner lines, progressing from the point of impact outward and downward. Hertzian cones may have more that one mirror segment due to interference by rebounding energy waves.

Overburden The surface and the substrate of the HFM target material around but not including the Hertzian cone. Term used in mining and archaeology.

P-Wave A seismic wave that travel at the speed of sound in the target material both annularly and perpendicularly from the point of impact. Also: Primary wave, compression wave and pressure wave.

Pap (Figure 28) A style of Hertzian cone named for breast-like, Pap hills and mountains of Scotland; Little Pap, Maiden Pap, Pap of Glencoe, etc., having a wider base that thins uniformly to a summit area with a narrow peak. Pap hills are often topped with a knob or tor at the apex. HC Paps have like features with wider base thinning at the lower edge of the spinner and can include a pedestal at the apex. Pap is from Scots and Old English meaning breast or nipple-like.

Figure 28 *The Maiden Paps, hills in the Border region of Scotland and a similar shaped Hertzian cone.*

Paranthetics (Figure 5) CSA's in earthen berms or crater walls that resemble parentheses.
Symbols = (P) one circ on right side = P) or on left side = (P.

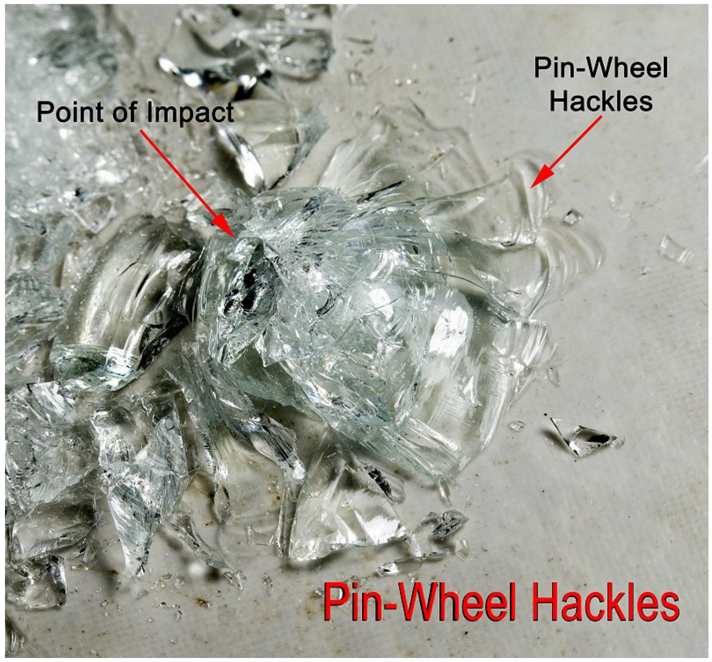


Figure 29 *A highly fragmented Pin-Wheel shaped HC with large, lobed hackles.*

Pin-Wheel Hackles (Figure 29) Hertzian cones that exhibit hackle features that resemble blades on a pin wheel or blades of a fan. They are usually found on highly fragmented Hertzian cones and are suspected to form in conjunction with high velocity projectiles with high-speed Y-axis annular rotation.

Plastic Deformation (Figure 28) The bending, stretching or compressing of a brittle material deformation like that in modeling clay. The material does not "snap" back into the original shape as can be seen in the recumbent fold at the base of Cavanal Mountain, Oklahoma.

Point of Impact/Point of Compression (POI/POC) The point of compression and fracture generation below the crater resulting from projectile impact, thermal or other rapid release of energy. Also includes rebound wave and heterogeneous geneses in secondary and additional locations within the HC.

Pore/Void Wakes (Figure 32) Viewable wavy fractures created by diverted energy around voids (bubbles) in glass. Shapes vary from flame-like forms to winged or braided or lanceolate trails from the direction of the fracture source to the outer extremities.

Fusilier Wake Voids having flaring, shadow-like wakes that resemble military fusilier insignia.

Tadpole Wake A void with a lanceolate trail opposite the point of impact.

Braided Wake Tadpole wakes with the appearance of braided tails.

Front Winged Wake Wakes that flare bi-directionally from the leading edge of a void to form wing-like features.

Back Winged Wake Wakes that flare bi-directionally from the back edge of a void, sometimes in conjunction with tadpole wakes.

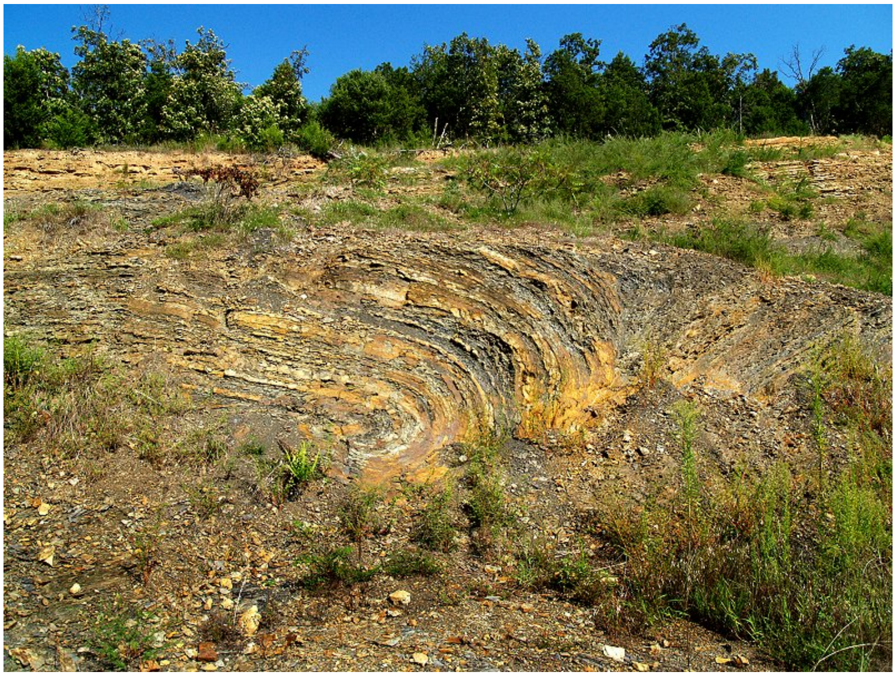


Figure 30 *Plastic deformation. A recumbent fold in Cavanal Mountain, Oklahoma.*

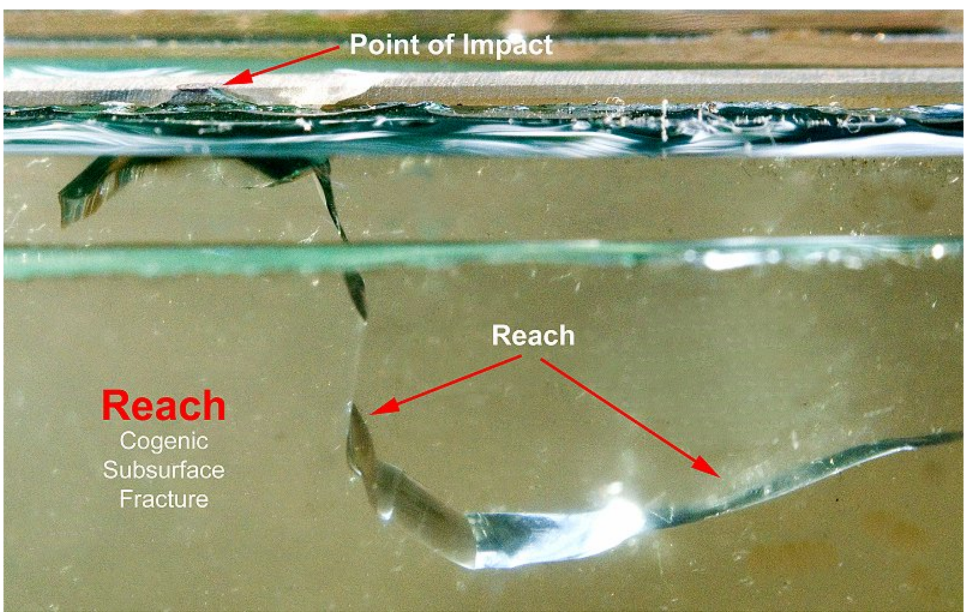


Figure 31 *Subsurface fractures under impact HC's that "dive" into the target material.*

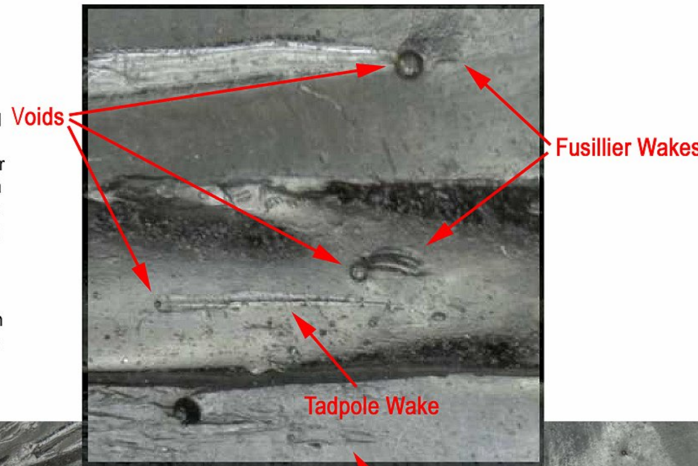
Radial crack Fractures starting at the point of impact and radiating outward like spokes on a wheel. See X-Fracture.

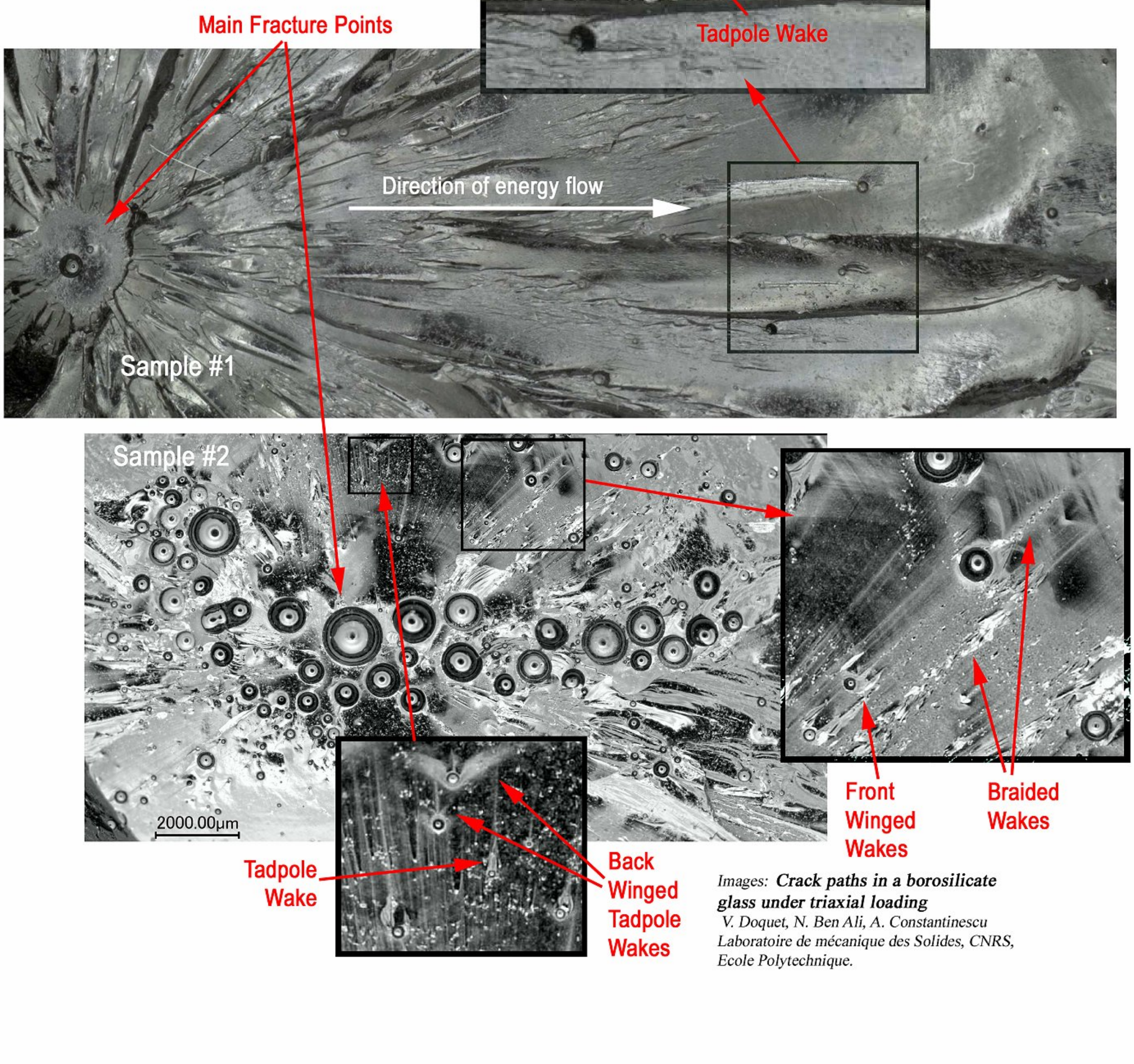
Reach (Figure 31) A fracture below a Hertzian cone that dives to lower depths in target material.

Rolling Contact Fatigue (**RCF**) Hertzian fractures in steel or metal rollers and gears. Also called, Hertzian contact fatigue, spalling, pitting.

Wakes in Hertzian cones

In preliminary studies energy wakes appear to form behind voids in borosilicate glass. It is suggested that this anomaly forms in other materials. Speculatively energy waves are forced around the void where they react similarly to deviation of waves around heterogeneities in other materials. However, it is not yet known if the area behind void is compressed the way shatter cones are created in rock or simply cause waves to turn aside. Here distinct trailing can be seen in differing patterns from straight-tailed, tadpole wakes, to fanned and winged formations beside and behind the pores. Here are examples seen in cold-to-hot induced Hertzian fracture cones along with current labels.





Images: ***Crack paths in a borosilicate glass under triaxial loading***
V. Doquet, N. Ben Ali, A. Constantinescu
Laboratoire de mécanique des Solides, CNRS, Ecole Polytechnique.

Figure 32 *Wakes on the lee side of voids in borosilicate glass after fracture.*

Scot's Jump (SCJ) (Figure 33) Recordable, directionally-divergent impact paths by a single projectile along the surface of a target. SCJ impacts can create unusually shaped HC's. The deviation is always recorded 0/360 degrees from the projectile path and not along the true-north compass as in the DoP record. SCJ-left and SCJ-right can be used generally when describing the deviation. The distance from POI center-point to center-point is taken and recorded starting from the second POI. In recording the protracted angles, indicate progression of impacts from the rebound from the first to last. SCJ with backspin can create craterfeatures to the reverse of the projectile trajectory.

SCJ record example:

> In a hypothetical SCJ fracture series in a flat sheet of glass: The first impact originated from a direction at 275 degrees from true north at an angle of attack equaling 30 degrees and bounced 2 mm. Then, viewing from the path of the projectile the second impact records a 330-degree deviation from the original path and bounced 1.2 mm. The third impact originated at 300 degrees from the original path.
>
> > Thus, three bounces by the projectile are indicated;
> >
> > First impact; DP275/AAT30d
> >
> > Second impact: CP2mm/SCJ2-330d
> >
> > Third impact: CP1.2mm/SCJ3-300d
> >
> > Combine to read - DP275/AAT30d; CP2mm-SCJ2-330d; CP; 1.2mm/ SCJ3-300d.

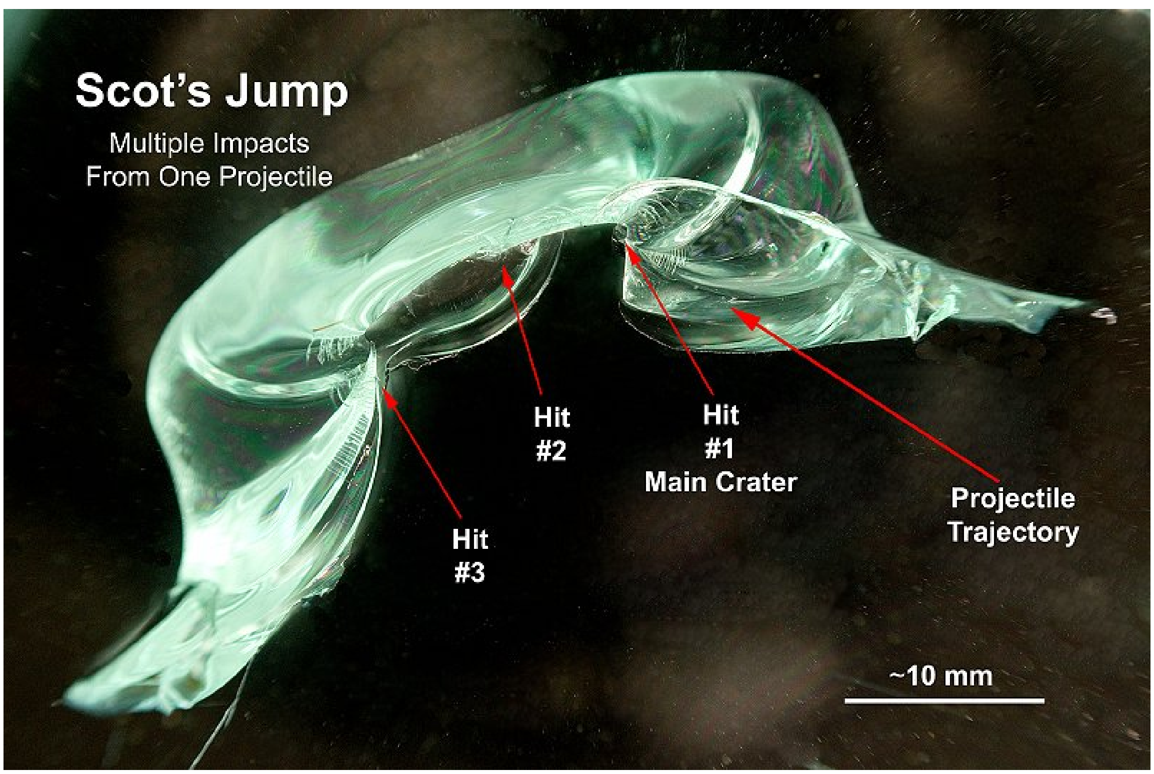


Figure 33 *Scot's Jump. Illustrated is a sample of a three-hit, Hertzian fracture in soda lime glass created by a spinning projectile.*

Sediment Fingerprints A study using quartz-sand-grain surface textures used to identify grain types by dividing them into varying types. It uses Hertzian and conchoidal fractures as differing features in the formation of sand.

Mechanical Features	Chemical Features	Morphological Features
Hertzian fractures	Dulled surface	Subangular
Conchoidal fractures	Carapace *(raised)*	High relief

Also included in the list of sixteen features are other forms of Hertzian erosion, Star fractures and Dish-shaped concavities. The study was undertaken to analyze sand grains from differing locations around Great Britain for use in forensic studies. From: Sediment Fingerprints: A forensic technique using quartz sand grains By Peter Bull and Ruth Morgan.

Segmentation (Figure 19) Divisions within a Hertzian cone due to crushing and fragmenting by the projectile or indenter. Segments can include the spinner, core, lamina and random fragments.

Separation Inertia (SI) The energy from the projectile, indenter or explosive force that separates the Hertzian cone from the overburden in an annular or semiannular progression. Also: Indenter load

Shatter Cone (Figure 34) Conical or semi-conical Hertzian fractures formed by bolide impacts in rock. They have feathered hackles radiating angularly from an apex away from the point of origin for the HC. Similar to feather hackles but more uniform in their bisectional form. Baratoux and Melosh describe them as being, "unequivocal fingerprints of meteoritic impacts on Earth." They are generally believed to form when compression waves strike and drive heterogeneities into surrounding rock creating tension fractures in the wake of the contact point. They are considered shock metamorphic features. Energy waves bouncing in rock can create "twin" cones with apexes in opposite directions.

Figure 34 *Shatter Cones discovered by geologist T.H. McElvain near Santa Fe, NM.*

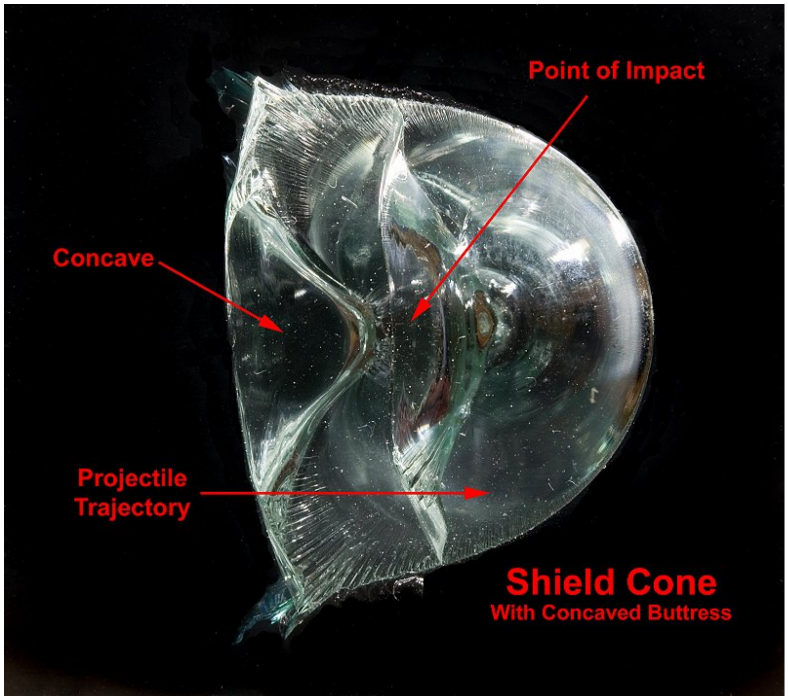


Figure 35 *Shield Cones may occasionally have concave buttresses.*

Shield Cone (Figure 35) A protruding flattened "buttress" section of a Hertzian Cone due to angle of attack or spin of a projectile. Shield cones may have indented, concaved buttresses due to high spin or shallow angle hits at the point of impact.

Sidespin Annular rotation around the XY-axis point along the projectile's line of travel; clockwise (c-spin) and counter-clockwise (cc-spin). Airplane propellers rotate in this manner to pull the aircraft along its route.

Sink Hole A separation of target material under Hertzian fractures during metal-fatigue experiments where an open void is created separately but directly below the crater floor of the point of contact. These can be seen in laser-metal fatigue experiments by Lawrence Livermore National Laboratory.

Spall In impacts, the breaking of target material into small fragments around the point of impact on a larger solid material. Impact craters are indicative of spallation in target material. It can also be produced by corrosion, weathering and cavitation. In surface failure, spalling and spallation are both used to describe the release of material around a specified local. It is used as a synonym for Hertzian fracture by T.J. Ahrens at Cal Tech in his studies on impact generated fractures in Coconino sandstone and San Marcos gabbro. In flint knapping a spall is a synonym for a flake. Exfoliation.

Spinner (Figure 36) An area around the point of impact that remains intact after the fragmentation of the base and body of a Hertzian Cone. It has been described by A Ball and HW McKenzie as resembling a spinning-top toy.
Also: Corn, Spinning top

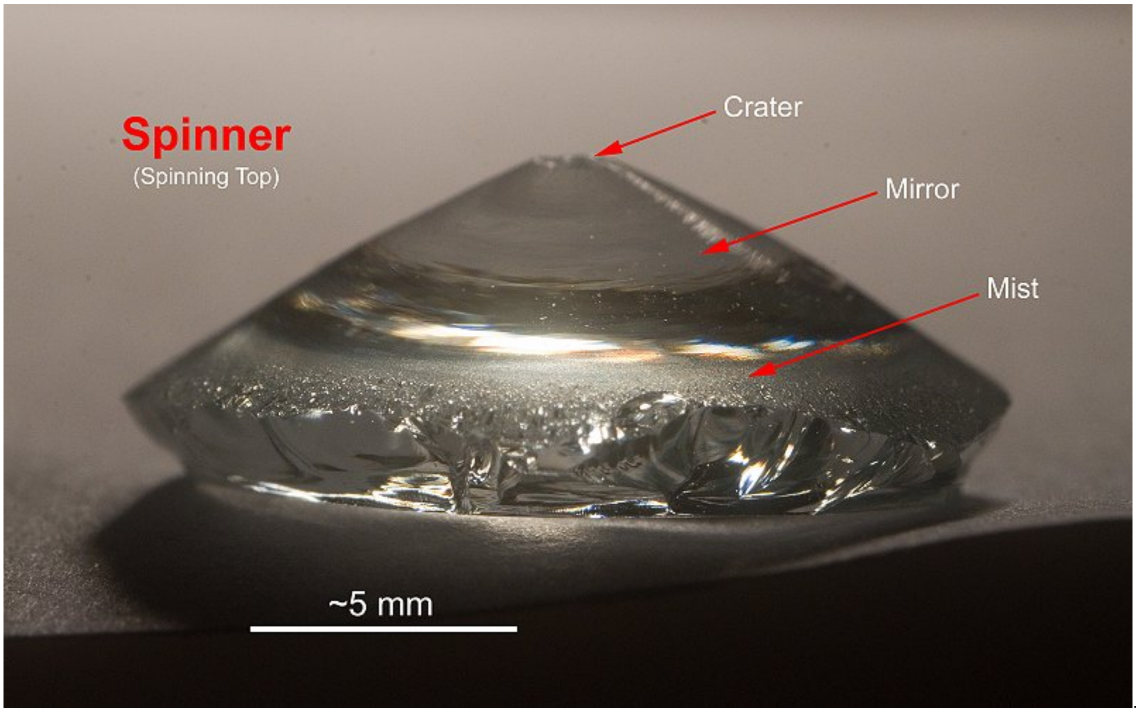


Figure 36 *A spinning top (spinner) segment of a Hertzian Cone. Sizes vary with percentages of cone fragmentation.*

Spread (SPD) The general diameter of a Hertzian cone or fracture at a determined distance from the plane of the target. A wide spread indicates a slower projectile velocity in relation to the type of impact and target. However, Ball and McKenzie report a wider base with higher velocity along with a narrower angle in the spinner section. Conversely, a narrow spread in higher velocity ballistic studies found by Miyamoto and Murakami concur with Dowd Research studies that indicate steeper cones in higher projectile velocities.

Spread can indicate differences in the shape of cone base or fracture. Spread may be taken at differing levels in the cone to record changes in wall angles. X and Y angles indicate the shape of the spread: X = 90 degrees from angle of attack, Y = 0 degrees. Other axises may be added with defined angles of degree for more detailed descriptions. Depth is determined from the mean level of the target surface.

Spread record example:

At a depth of 5mm in a horizontal sheet glass the width of the HCF is 15mm on the X axis and 20mm on the Y axis: Depth-5mm, X-15mm, Y-20mm; Depth-2mm, X-5mm, Y-7mm.

Star Fracture *See X Fracture below.*

Static Loading In making a lithic blade, the application of force by placing an indenter on an object that is to be flaked and applying load to break the conchoidal segment from the body of the object. Also Pressure flaking.

Strain Deformation in the shape or size of an object as a result of applied stress.

Stress A force that causes strain.

Tension Forces which pulls portions of a body apart.

Tensile Stress A stress that pulls two or more areas of an object apart.

Tensile Strength The strength and ability of a material to resist tensile stress.

Tensile-Axial Stress A force or system of forces that tend to elongate a body in the direction of applied energy. Also, axial-tensile stress. Antonym, compressive stress.

Terraced Cone (Figure 37) A Hertzian cone possessing annular, concentric undulations of lamina in stepped sections. Segments are created by P-waves bouncing from strata or back planes to force inertial waves slightly outward before they continue through the body of the cone. Terraces are apparent when overburden is removed and segments slump. A feature that is similar to Wallner lines but greatly exaggerated and fractured.

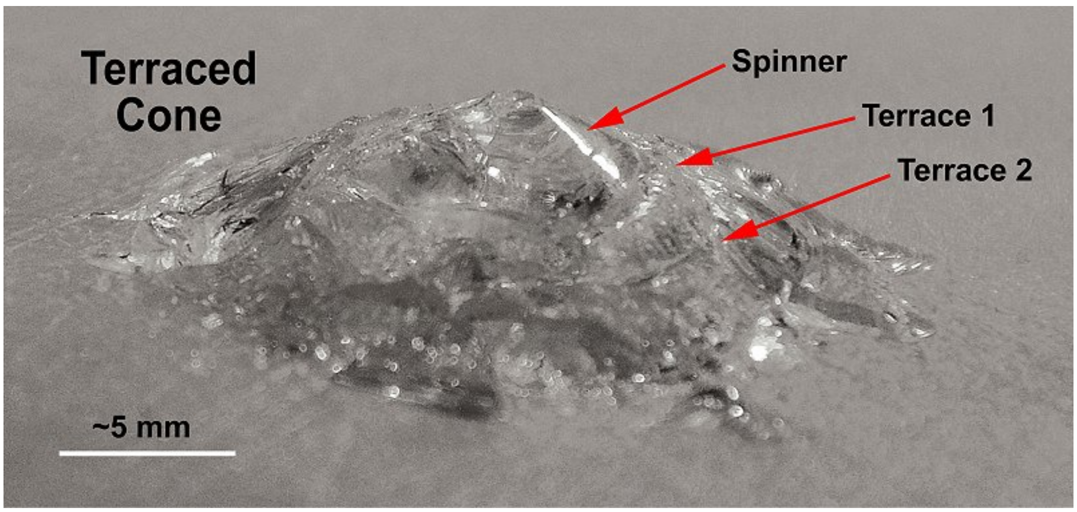


Figure 37 *A Terraced Cone with two tiers and star-like radial lobes.*

Triangulates (Figure 6) A crushed or fractured section of a Hertzian cone lamina displaying clustered triangle shaped segments within the body or laminae.

Vitreous A material with glassy, amorphous texture (without shape) such as glass, films and gels.

Wallner Lines (Figure 7) Wavy, rib marks or ridges in the wall of a Hertzian cone or mold undulating in sequence created by bouncing energy waves during formation.

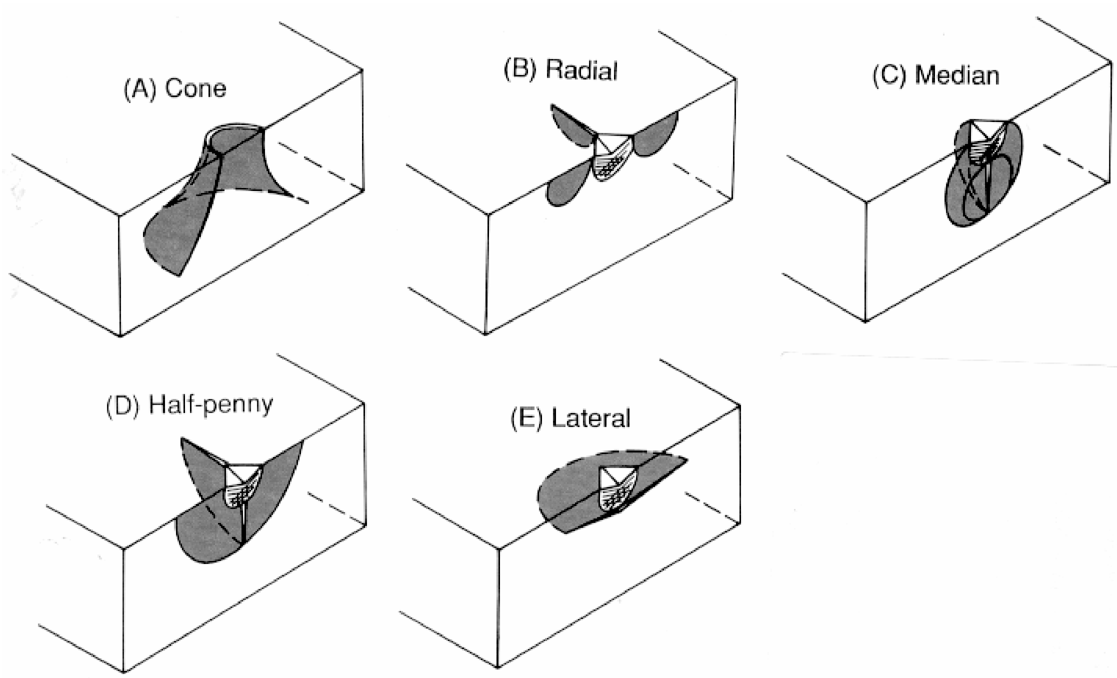
X-Fracture/Star Fracture *Figure 38* A tensional fracture from impact initiated at the bottom plane of glass or strata. Crack genesis forms below the surface and creates outward radial lines that resemble an X or a star. Also called a Lily Fracture.

***Figure 38** An X or Star Fracture created when projectile bends target material creating a fracture from a lower plane or strata. The feature is sometimes call a Lotus Fracture due to parabolic, petal-like fractures from the main HC as seen above.*

Yield Strength Yield strength or yield point in materials is the stress point at which a target material deforms plastically. Prior to plastic deformation is the elastic phase where a material will return to its original shape.

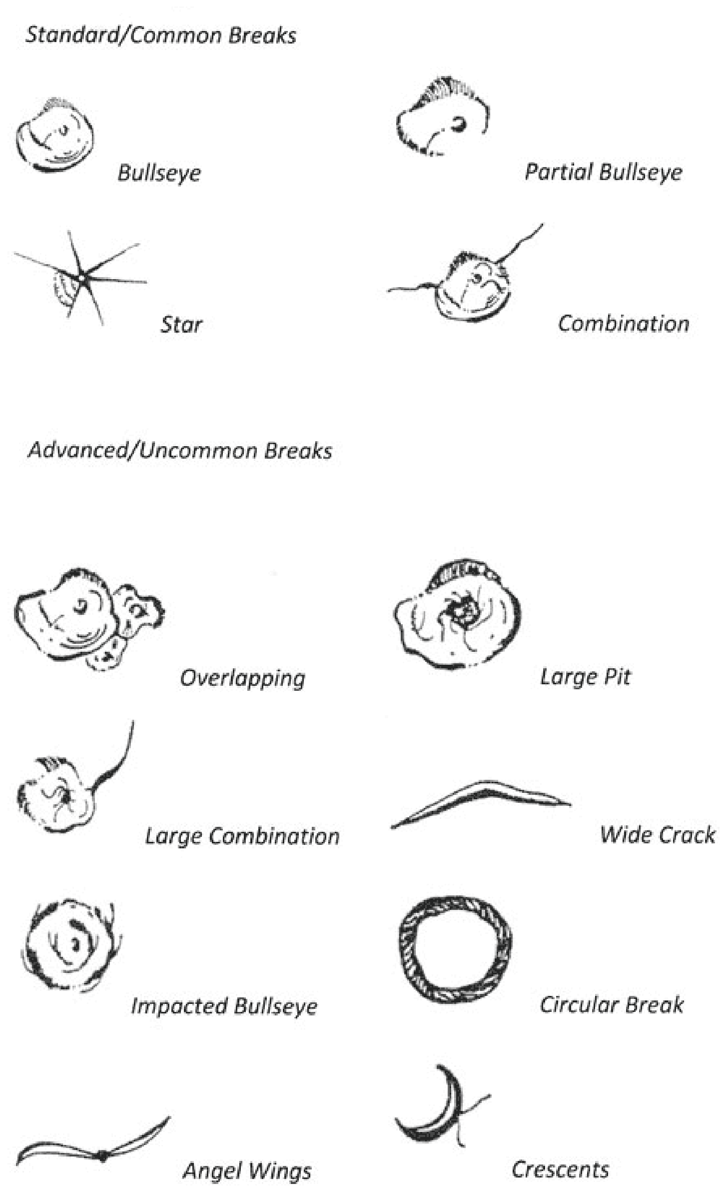
Appendix 1

Figure 39 ***Terms used in:*** *A General Introduction To Fracture Mechanics and Mechanical Strength of Materials Or: Why do things break and what can we do about it? Figure 36, den Toonder, Jaap M.J., Unclassified Report, © Philips Electronics 1998*



Appendix 2

Figure *40* *From: Standard and Common Breaks, ScottGlass.com. Windshield repair industry terms*.



Appendix 3

Images from T.J. Ahrens, et al, Cal Tech

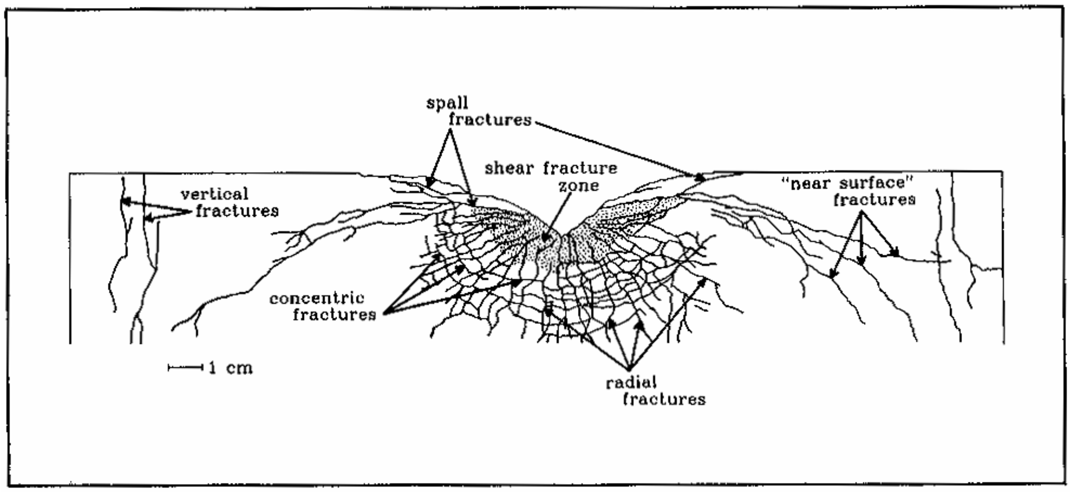


Figure 41 *T.J. Ahrens, et al, Cal Tech. Image of Figure 5, cross section of target in San Marcos gabbro.*

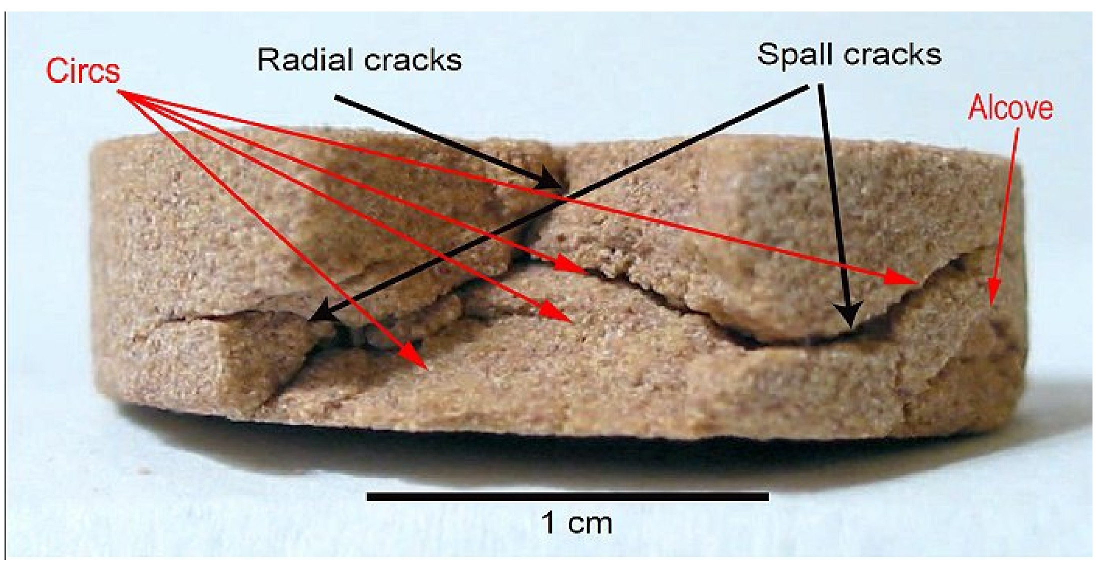


Figure 42 *T.J Ahrens, et al, Cal Tech. Image of spallation in Coconino sandstone. Note the circular features in the main spall and the alcove to right of image. Red lettering and arrows added for this glossary.*