THE PHYSICS OF CROP FORMATIONS

by

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In 1989 the appearance of two books on crop circles, combined with some media coverage, alerted most Americans for the first time to the appearance of a previously unrecognized phenomena which had no precedent: large, geometric-shaped areas of crop which had been flattened overnight.

Writing a letter to author Pat Delgado to ask for details on the biological studies, career biophysicist W.C. Levengood was shocked to find that no biological studies were being conducted. He asked for and received plant samples taken in line with his instructions, in what was to become a steady stream of plants across the Atlantic. As formations were reported in the U.S. and other countries, samples were obtained from them as well--always with control samples taken from unaffected parts of the same field for comparison. Today, after meticulously analyzing tissue samples from five countries and more than 300 formations involving many types of crops, some clear patterns have emerged.

Whatever the force which makes crop formations, it physically alters the tissue of the flattened (and sometimes the internal, upright) plants in a number of ways. Over time an hypothesis has emerged suggesting plasma as the active force. None of the following effects has occurred when formations have been made (by us and others) using all the techniques claimed by those who have "confessed" to hoaxing the crop formations:

1. Stalks which are very often bent up to ninety degrees without being broken, particularly at the nodes (which are like the joints of wheat stems). Something softened the plant tissue at the moment of flattening. This is particularly dramatic in canola (rapeseed), which otherwise is as stiff as celery at this stage of development.

2. Stalks which are usually enlarged, stretched from the inside out by something which seems to heat the nodes from the inside. Sometimes this effect is so powerful, the node literally explodes from the inside out, blowing holes in the node walls and spewing sap outside the stalk. This has been measured in thousands of samples to a degree of 95% to 99% probability ("significant" to "highly significant" in the language of science). Levengood has duplicated this effect using microwaves.

3. Stalks which are left with surface electric charge. We have measured this in two formations which were only a few hours old. The degree to which the stalks were bent over was proportional to the degree of electric charge on the stalk, strongly suggesting the force which pushed it over was electrical.

4. The thin bract tissue surrounding wheat seed which has had its electrical conductivity increased, consistent with exposure to an electrical charge.

Natural Causes

As scientists we (the BLT Team) had to next ask if there is anything in nature which shares these characteristics. The answer is yes--plasma. Plasma, here, is simply electrified air. It carries electric charge, and when it travels through a magnetic field (like the geomagnetic field which exists everywhere on the planet) it does two things:

1. It moves in a spiral, the most common pattern in which crop is flattened (in crop circles).

2. When it spirals thus it emits microwaves. (This is the same principle used in your microwave oven, where electrons are spun around a magnet in the roof and emit the microwaves which penetrate the tissue, heating from the inside by interacting with

the water in the food. The plant stem nodes, the most affected part of crop formation plant samples, are the site with most of the plant's water.)

Plasma was first hypothesized as the cause of crop formations by English meteorologist Terence Meaden. He suggested the plasma was in the form of a vortex produced meteorologically. Unfortunately crop formations did not seem overly dependent on any set of weather conditions, and this model did not explain non-circular formations.

We asked ourselves, was there any *other* possible source for plasma? Lightning is an example of a very powerful, very high-energy plasma. It is caused by plasma (electrically charged air) far above ground in thunderheads up to eight miles high being attracted to opposite charges in the ground. But lightning is a much higher energy plasma than that which makes crop circles (where usually no charring occurs).

Low-Energy Plasma

The ionosphere, on the other hand, is a region of low-energy plasma 40-80 miles up in our atmosphere, where most of the air is electrified by solar wind and cosmic rays. The only time that some of this plasma gets energetic enough to glow is when we see the Northern Lights. It was long believed that the ionosphere and the earth's surface were completely separate, and that never the twain would meet. In recent years, however, decades of airline pilot sightings were confirmed with scientists' photos of electrical flashes in the air between thunderheads (8 miles high) and the ionosphere (up to 100 miles high). The several types of these have been dubbed "sprites," and they are apparently very common events. So there *are* frequent exchanges of electric cargo between the ionosphere and a storm 90% of the way to the earth's surface.

We believe that sometimes the exchange may cover the other 10% of the distance as well, and actually reach the ground. Something similar is known to happen every night everywhere when plasma penetrates part-way down (causing perturbations in the geomagnetic field). Normally these attempted penetrations are bounced back the way they came by the reflective layers of the ionosphere--the same reflective layers which AM radio waves bounce off to communicate over the horizon. At night these layers weaken and rise (which is why you can get AM radio reception over much greater distances late at night).

They are weakest in the predawn hours, when most crop formations occur. The ability of plasma to penetrate these reflective layers is directly proportional to its "vorticity" (i.e. the tighter and more rapidly spinning the plasma cloud, the further it can penetrate toward the ground). The "magnetic pinch" effect insures that as such a plasmoid descends toward the earth's surface, it shrinks in size and spins faster (much like spinning figure-skaters accelerate by pulling in their arms).

An Increase in "Ammunition"

The amount of "ammunition" in the ionosphere, in the form of free electrons, increases up to 100 times between sunspot maximum and sunspot minimum. Crop formation frequency, at least in England, has roughly paralleled sunspot numbers. The huge outbreak of crop circles in 1988-1989 coincided with the most powerful sunspot maximum in their 170 years of recorded history--since 1988-89 crop circle numbers have declined accordingly. This roughly 11-year-cycle should peak again near the millennium.

The MeteoriticConnection

The strongest evidence for the ionosphere as the origin of crop formation plasma comes from microscopic particles of meteoritic dust found in two-thirds of the 32 formations where we

have been able to obtain soil samples. The heaviest concentration ever was found in 1993 in an English formation which appeared on the night of the largest meteor shower to hit Europe in 30 years. This example became the basis of our second (1995) paper on crop circles, published in the peer-reviewed literature ("Semi-Molten Meteoric Iron Associated with a Crop Formation," *J. Sci. Exploration* 9:191-199).

Sub-millimeter-sized bubbles of pure iron oxide (magnetite) coated both the ground and the crop in that formation. To summarize a detailed and technical investigation, the material was identical to the debris which erodes from meteors as they burn up in the atmosphere, and which takes 7-10 days to settle to the ground. It can be picked up with a magnet (as could some of the wheat in which it had become imbedded). It has since appeared in the majority of formations from 13 U.S. states and 5 foreign countries where soil samples were obtained. Inside formations, it appears in 20-100 times the normal concentration for soil.

As plasma spirals around geomagnetic field-lines it creates its own magnetic field. This would tend to attract and carry along any magnetite dust particles encountered as it descended from the ionosphere. The ubiquitous presence of this material has essentially ruled out a low-altitude source for the plasma.

Established Scientific Facts

These are extremely well-established and long-established scientific facts. Nothing said so far is remotely controversial, except for the idea of plasma reaching the ground from the ionosphere. Plasma loves to organize itself into spirals: most aurora are actually arrays of tight tubes of plasma vortices, seen from the side as they spin around the geomagnetic field lines. One-third of all aurora organize themselves into gross spirals, as well. One candidate--the small curl--seems a likely candidate for crop circle formation. It is often as small as 400 meters across where it starts in the ionosphere, but shrinks as it descends.

Plasma might, we reasoned, be reaching the wheat fields of England from the ionosphere, but why did so many occur in one small area of England--and how did they form some of those incredible patterns? These are two very distinct issues. In a search for why any plasma might be particularly attracted to one tiny area 30 miles or so across, we eventually looked at hydro-geological maps of England and found something remarkable.

Crop formations in England overwhelmingly appear over shallowly-buried parts of a giant chalk aquifer. England has the world's deepest chalk aquifer (the white cliffs of Dover are a view of one side of it). They also have some of the world's greatest seasonal fluctuations of water levels--up to 100 feet. Was there anything about this which might attract plasma? As it turned out, there was. Water percolating through porous rock--any kind of porous rock--creates electric charge. This occurs by a process called "adsorption," in which electrons are stripped off water droplets as they move through rock pores, leaving a net negative electric charge behind on the rock and a net positive charge on the water which drains through.

Chemical Reinforcement

With calcium carbonate (the mineral which makes up chalk) there is a chemical process when the water dissolves some of the mineral, which further reinforces this same charge separation. Wherever charge separation occurs in a body which can conduct electricity, electric current flows and generates its own magnetic fields. We measured these ground currents and their changing magnetic fields in 1993 at Silbury Hill, long the center of the most intense crop formation activity in the world.

Relationship with Aquifer

Crop formations in southern England overwhelmingly occur where this electrically-charged rock is closest to the surface. The largest formations and most frequent formation happen late in the summer, when the aquifer is most run-down, and the most water has, therefore, run through the most rock. The beginning of the modern phenomenon of large, spectacular formations began in the late 1970s and early 1980s, a time when over-pumping for public water supplies began to lower the water-table noticeably in the Wiltshire area. Elsewhere it has been noted that droughts have coincided with banner years for crop formations.

In one particular field in England which has nearly annual crop formations, our team measured the kind of magnetic fields one would expect to accompany such electric ground currents; four days after taking these measurements a major formation occurred there. Follow-up fluxgate magnetometer measurements, taken four days after this sixty-foot dumbbell appeared, showed that the magnetic readings and the currents which produced them had vanished. This is not unlike the discharge with that more powerful plasma--lightning. In the case of lightning, ground current attracts the airborne plasma, and when the plasma (the lightning bolt) hits the surface it neutralizes the ground current.

Limestone is the chemical twin of chalk: it too is calcium carbonate, but it is much less porous than chalk. It also has the ability to generate ground currents from interaction with water, but not nearly so much as chalk. This it is fascinating to note that limestone aquifers are the major exception to crop formations occurring over chalk substrata. Formations in England do happen a minority of the time on the large limestone aquifers there.

In the U.S. we have no substantial chalk deposits, but huge stretches of limestone aquifers do exist in Florida, on the Eastern Coastal Plain, throughout much of the Midwest, and virtually all of the Great Plains, extending into Canada. Finally, a thin stretch runs down the West Coast. These locations are where crop formations occur in the U.S. As in England, the most active sites seem to frequently be where an edge of the aquifer occurs or where a river valley has cut through the aquifer to produce an edge. Proximity to water is also typical (no surprise, considering the current generated between water and the rock it runs through).

Shapes Most Difficult to Explain

This leaves us with the question of shape, the crop circle designs--the most difficult aspect to explain with a natural model of crop formation causation. The most common patterns in the crops are the most common patterns seen in plasma in the laboratory. It is important to remember that plasma is *scale-invariant--anything which happens on a scale of inches can and will happen on a scale of miles, etc.* So it is worth noting that plasma in the lab most commonly organizes itself into a spiral--the most common pattern found in flattened crop circles. The next-most common pattern observed in plasma is the swirled disc, surrounded by concentric rings (the crop circle "bulls-eye" or "target" pattern), and this is also the next most commonly observed design in the fields. Furthermore, in both mediums the concentric rings tend to alternately swirl clockwise and counter-clockwise as you move out from the center (or in from the edge).

Other Patterns

Other patterns seen in plasma and in crop-fields include floral patterns, nested crescents, dumbbells, and others. The designs hardest to understand using the plasma model are those that incorporate straight lines and right-angle shapes--it is counter-intuitive to think that air can form such patterns. However, as electrified air, plasma behaves more like an electromagnetic fluid (and, so, the physics of plasma motion is called "magnetohydrodynamics"); and, while it is also contrary to common sense that liquids form such shapes, in fact they do--*when excited*.

American physicists exciting liquids with sound waves have produced surface ripple patterns that include squares, triangles, hexagons, and others. We must remember that a crop formation is the two-dimensional record of the passing of a likely three-dimensional shape--the ground (2-dimensional) is likely to record only a 2-dimensional slice of a 3-dimensional plasmoid. So even 2-dimensional patterns in the plasma could get recorded on the ground.

Deterministic Chaos

Deterministic chaos is a new branch of science which has repeatedly shown that systems which are excited or turbulent can assume surprisingly geometric patterns. Ilya Prigogine received the Nobel Prize for showing that 2-dimensional geometric patterns often form of their own accord in 3-dimensional pools of liquid chemical reagents.

A ball of plasma being drawn ground-ward by an electromagnetic hot-spot is likely to be a turbulent system; as such, we can expect that patterns will spontaneously arise within the plasma, however briefly. If at such a moment the plasma impacts the ground, whatever pattern had formed is the pattern we can expect to appear in the crop. Also, with plasma there is a positive feedback loop which might tend to refine certain patterns until they are of the picture-perfect sort we so often encounter.

Certain shapes called "waveguides" will attract plasma like bees to honey. A rectangle is one such shape and this is a primary reason why ball lightning (a high-energy plasma) loves to enter houses through the chimney--chimneys are rectangular tunnels.

Another commonly used waveguide in industry is the dumbbell shape (which occurs frequently in the fields), and still another is the "key" or "F" shape (called the Millman Waveguide) which we often see attached to circles.

Plasmas create their own magnetic field-lines. If, by random chance, the magnetic field in a turbulent plasma takes on a waveguide shape, it could create a positive feedback loop. More plasma will be attracted to that part of the plasma ball, vortex, or cloud which has assumed that shape. The plasma will spiral along those magnetic field-lines as it moves; when plasma spirals around a magnetic field-line it strengthens that field-line, which in turn attracts more plasma, etc. Thus this shape might tend to get "locked in" and even refined until close to its ideal shape. At the moment this is a highly speculative, but stimulating, hypothesis. It still strains the imagination to think how some of the more elaborate patterns might arise from sheer plasma physics.

Not Always Perfect

One aspect of all this that has long bothered us is that, if this is a natural phenomenon, then it should frequently result in designs which are not "geometric" at all. Nature does not always get everything perfect. As it turns out, we now believe that *most plasma impacts result in non-geometric* flattening of the crop. Of course, crops around the world are constantly being flattened by non-plasma events such as wind. However, sometimes close inspection of such raggedly-downed areas has revealed the same bent and elongated nodes as are found in crop circles. Sometimes a large field in which the crop has been flattened in a non-descript pattern will have within it small areas of spiraled lay and other lay patterns (with 180 degree opposition) which are impossible, if wind were the cause.

Sampling and lab analysis of many such sites has shown a great number to have the same tissue changes as in formations. In fact, the most dramatic node changes ever recorded have been in such randomly-downed areas--including plant stem nodes which were blown apart from the internal pressure. This is in keeping with plasma physics: plasma will spontaneously organize itself into a vortex shape--if the energy level of the plasma does not get too high. When the energy level exceeds a certain threshold, the plasma's ability to maintain the vortex pattern breaks down.

Examination of photographs of crop formations very often reveals such ragged areas of downed crop all around a formation. Our pattern-seeking minds, however, tend to ignore this, and we go straight to the geometric formation, considering this to be the only "genuine" event in the field.

We believe that plasma, in whatever shape, is probably impacting the ground far more often than we realize. We have analyzed rings in grass which have undergone physical changes consistent with plasma contact. If plasma were to hit streets or buildings it would leave no visible record. A series of concentric rings found in sand on a U.S. west-coast beach showed very high levels of ionization; a ring in dirt in a Colorado field had some of the highest concentrations of meteoritic dust we have ever seen (and this only in the top three inches of ground and only in the ring).

Like Sprites?

We believe that the plasma we are studying may turn out to be like sprites. Their existence, reported for decades by airline pilots, was ignored by science until a professional scientist took photographs of them. Now that scientists are looking, they are discovering sprites to be incredibly common, wherever there are thunderstorms. We have one daytime photograph from a crop circle in New York state which looks like a small plasma vortex, and the rare eyewitness accounts of circle formation are essentially consistent with our model. Likely one day everyone will know of such events. In the meantime we have those amazing patterns to admire and puzzle over.

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