Detonation Theory (part 01 of 02)

By Bruno Pimentel.

Hello my friends, I hope you all had a good New Year's Eve, and even if it's late, I take the opportunity to wish you all a happy 2023 with lots of health, happiness and success.

We stayed the months of December and January without making any publications, as they are festive and vacation months, in addition to the fact that I was moving, so I took the time to settle in and enjoy the family in the new routine, but we hope now to be returning with our biweekly publications and although the new routine is well pulled, we will try to keep the publications in days.

So without further ado, let's go to another article in our Newsletter on rock blasting with explosives, and as always, we leave here the links so you can check our previous articles, as well as register, so that you are automatically notified with each new one. article we publish (now monthly):

Português

https://www.linkedin.com/newsletters/blast-de-rocha-c-explosivo-6941709482355748864/

English

https://www.linkedin.com/newsletters/rock-blasting-6959820770344595456/

These days I was thinking how much people who work in related areas are curious and interested in blast, including a lot of people always like to guess, and as in any area, many have no idea what they are talking about.

Including talking to a friend, he told me about a speech he had where the basic concepts had already gone to the air a long time ago and each one came with an outlandish theory to solve the problems of the blast, and as I always say, everyone has great ideas, the difficult thing is to make them come true... kkkk....

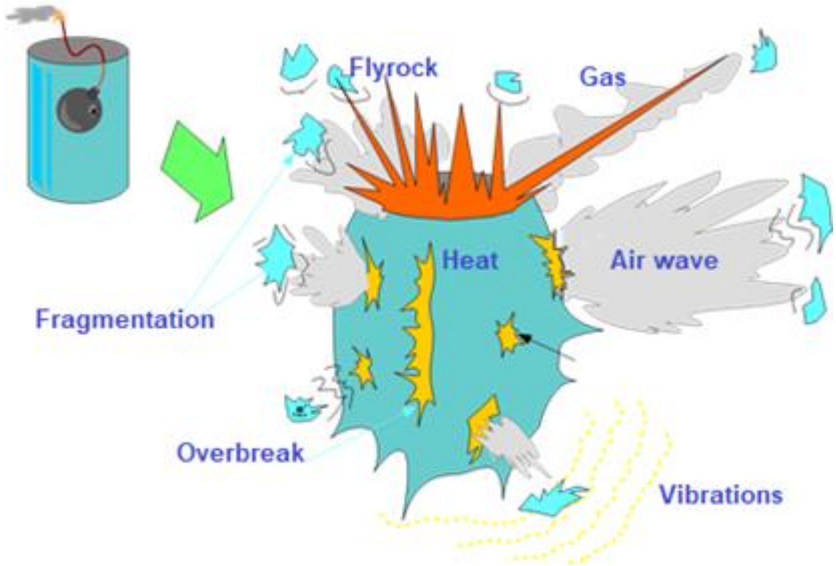
So I decided in the next articles to do a general review of the basic concepts and theories about the blast and the fragmentation of rocks, which despite being totally connected, within the blast, we need to understand first how the explosive detonates and what are the reactions or effects generated for this blast, so that later you can understand how they act on the rock and especially how the rock reacts to being impacted by the effects of the blast.

Remembering that we always try to give an overview and we will not go into details or discussions of which theory is the best or not, and that we will try to make some comments on the most accepted concepts and those that are easier to apply in everyday life.

So in today's article we are going to start commenting on the main points of the explosive blast process, considering that this explosive will be placed inside a hole in the rock, reviewing some important theories and concepts, so that from there we can follow the line of reasoning to throughout the blasting process.

Despite being a very theoretical topic, it is very important, and it would be good if everyone involved with the blast knows these basic concepts well, because they help us to understand what are the possible effects during a blast, both beneficial effects, which they will generate the results we need, such as effects with high risk potential, which we need to be aware of in order to avoid them during the process.

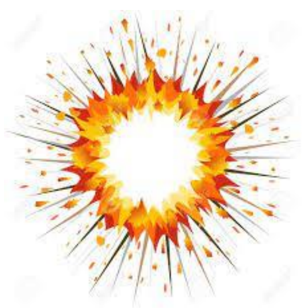
Another important point about these basic concepts is that they help us to better understand the need to control the preparation and quality of our detonations, as we begin to better understand what we need to do, so that during the blast process, we can take advantage of the maximum the energy released by the explosives to achieve our objectives.



So without delay, let's go to our theme for today!!!

DETONATION PROCESS

Introduction

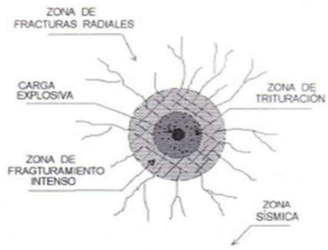


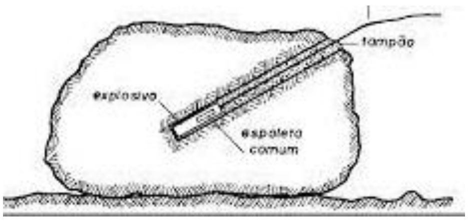
In general, normally when thinking about the blast of any explosive, the image on the side comes to mind, where we think of a point charge exploding from its central point, as the process is so fast that we consider that the explosive detonates instantly. So we usually don't consider the shape of the explosive, its size or quantity, nor the environment where it is detonating and acting.

With that, we always imagine the shock wave as a sphere that comes out of the center point of the explosive and expands, as in the figure below, where we can observe the contour of the shock wave generated by the blast of an open-air charge, or that is, without confinement, and in it we can observe the upper half sphere of the shock wave generated by its explosion.

So it is common to start most theories about blast considering the explosive as a spherical and punctual charge, which releases its energy equally in all directions around it, considering that any point within the same radius would receive the same energy level and would suffer the same effects.

When we bring this to rock blasting, an example closer to this theoretical scenario would be to think of the ideal case, where we would have to detonate a block of rock, and we could assume that this block of rock is a perfect sphere, and that we would be able to place a spherical explosive charge in its center, so when we detonate this charge, supposedly we could consider that its energy would be released equally in all directions, maximizing its effect on the block, and with that, we would have a greater use of the energy of the explosive and a result fragmentation of this well-standardized block along its entire length.



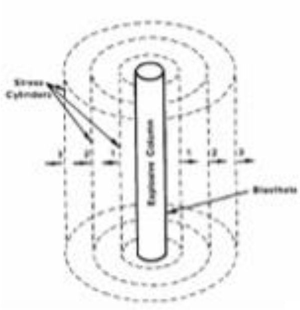


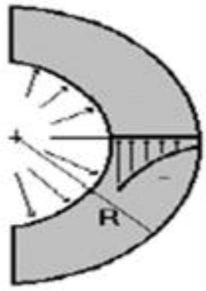
But this is a hypothetical scenario, which despite the fact that many theories consider it that way to be able to perform energy calculations more easily, in reality, even when detonating a block of rock, we know that we will not have a sphere of rock, but an irregular shape , made up of a rock that changes its characteristics along the block, and even more, we have to drill a hole or use alternative techniques to be able to place the explosive, which will have a totally different performance in each situation, according to the real characteristics of each scenario, and its effect will vary according to the conditions of the rock and its application.

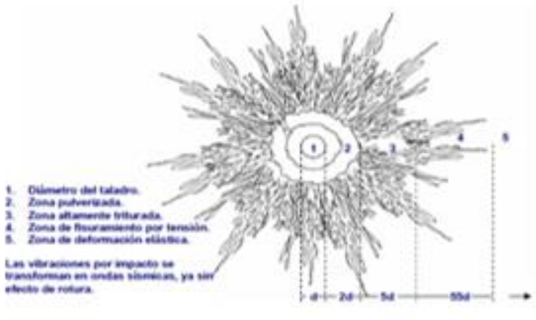
So, in summary, not to go into too much detail in theoretical considerations, we can say that in practice, this does not happen, firstly because we do not have point charges, with the exception of small detonations where we place a small amount of explosive, where we could neglect the shape of these charges, but apart from these few cases, in general, we can say that our explosive charges are cylindrical, because they will be inside the holes at the time of their blast, and this will directly influence the blast process due to the way the energy will be released. Furthermore, the rock that we are going to detonate is not perfectly distributed around the explosive charge, and it changes its properties and conditions, in addition to the fact that it is not isolated, which causes the energy to exist in a different way in each part, in addition to that we have a series of other points that will affect the action of the explosive on the rock, and this will affect the blast process, and thus the rock fragmentation process.

Then, even considering that the blast of our charge occurs very quickly, it still does not occur instantaneously, as there is a process for the explosive to be triggered and in turn causes the complete blast of the explosive charge, and this process takes an interval of time, which is really very short, but it exists, and it is necessary for it to occur so that there is a complete blast of the explosive charge, and that is why we cannot ignore it in the blast process.

So when we are going to analyze the blast theory, applied to the blast of rocks, we cannot only consider the blast theory of an explosive acting on a rock, we need to consider the whole process involved, including the shape of the explosive charge, its blasting process, its release of energy, the characteristics of the rock and its conditions, as well as the dispersion of energy in this process.







Initiation of explosive charge

So, leaving the theoretical scenario aside, first we need to consider that in our standard rock blast scenario, whether in the open or underground, what we have is a cylindrical charge, inside a hole made in the rock, and that when this charge is triggered, it does not detonate instantly, as there is an initiation process, which will cause the main charge to be triggered, usually at one end of the hole, and after that, we have another process, which will be the continuity of the reaction generating the blast of the rest of the explosive charge distributed along the hole.

Therefore, the first point we need to understand is that the blast process is initiated through an initial estimate, which we usually call activation energy, as it consists of the minimum energy necessary to initiate a given explosive.

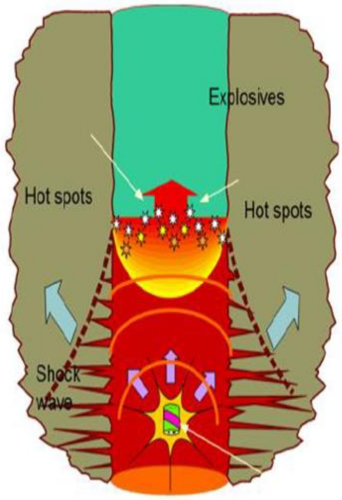
In rock blasting, we will normally use initiating accessories to provide this initial stimulus, and one of the basic rules for initiating an explosive is that the initial stimulus used is energetic enough to break the stability of the explosive to the point that it will react, that is, detonate, triggering the beginning of the chemical reaction of the constituents of the explosive, causing it to start the blast process.

The blast reaction will start at the point where it received the stimulus and will extend along the explosive, self-propagating and intensifying with the reaction of the explosive itself as its charge detonates.

This process will continue to occur throughout the explosive, until it reaches its blast speed, and from then on, it must continue until the entire explosive mass is detonated.

Normally, both the initial stimulus and the explosive blast itself generate shock waves, which travel through the explosive mass, and this is what directs the blast reaction throughout the entire explosive. Where the speed of these waves and their intensity are what will determine the reaction speed, that is, the blast speed.

Ideally, we want the initial stimulus to exceed the maximum energy of our explosive, so that it can release shock waves, and initiate the explosive, at a speed greater than the maximum speed of the explosive, and thus, from the beginning, the explosive can present its maximum performance, that is, its maximum blast intensity, so that the reaction of continuity and self-propagation of the blast will be stronger and more efficient.



This we apply in practice, following the concept that the initiating explosives must be more powerful than the main charge, so that they provide an adequate stimulus for the maximum performance of the explosive, and we can consider this as one of the main points to be able to maximize the release of energy from an explosive.

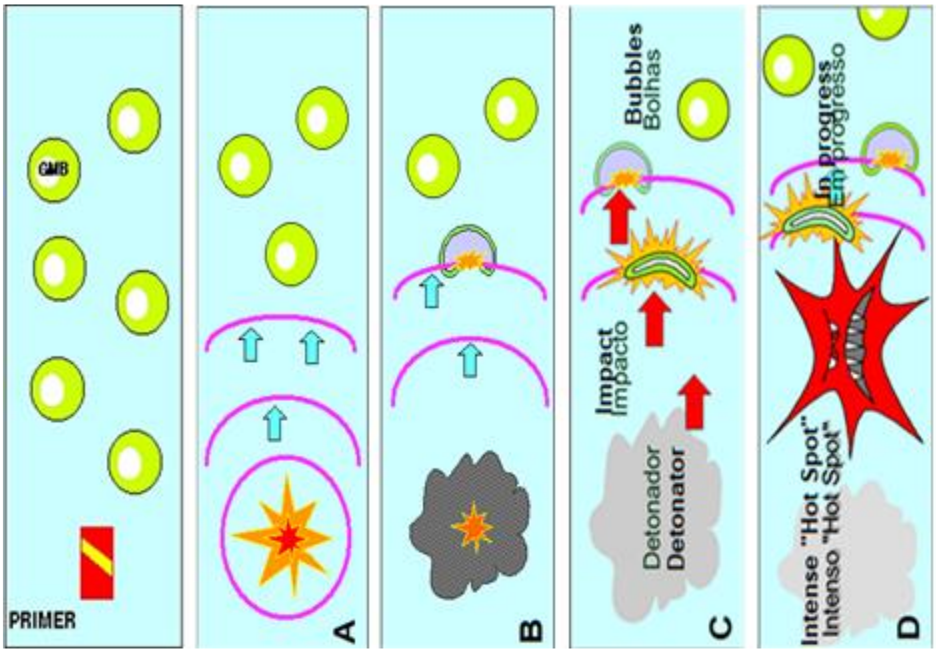
When we have a weak initial stimulus, but which exceeds the minimum activation energy, it will start the explosive, but at a low reaction speed, and the explosive will need a longer time to enter into regime and reach its blast speed standard, which means that we have a low initial performance of the blast reaction, and even, in many cases, we may have inefficient reactions or even deflagrations, where the explosive will not be able to achieve efficient self-propagation, losing much of its performance.

Propagation

Once the explosive has been efficiently initiated, the next step is to understand that only a part of the explosive (the one within the range of the initiator) will be triggered by the initial stimulus, and this part will be responsible for initiating the propagation process. of energy throughout the explosive, continuing the blast process, and this we call blast self-propagation.

To understand the process of self-propagation of an explosive blast, already considering the real scenario, that is, inside a hole, we first need to disregard time, because this happens very quickly, but to better understand the process, we can make a division of events in four stages.

We can follow each step in the tables in the figure below, where we initially have our hole, with the primer that will be responsible for generating the initial stimulus for activating the explosive charge, which in this case the most typical example would be that of an explosive emulsion.



So in frame A, we have the first phase of the process, which is when the primer or initiator detonates, and with its blast, it generates the initial stimulus, which generates shock waves that will impact the explosive and start the reaction of blast

Then, in frame B, the shock waves generated by the blast of the initial stimulus will reach the explosive, compressing the microbubbles, known as “hot spots” or sensitivity points.

By compressing the microbubbles, as we see in chart C, they will be under pressure, causing their internal pressure and temperature to rise more and more.

Then, as we see in frame D, the microbubbles at high temperatures will break, initiating the blast propagation process in the explosive. When this occurs, they generate more shock waves, which will continue propagating through the mass of the explosive, compressing other microbubbles, raising their temperatures until they break, and this generates a chain reaction, which we call self-propagation of the blast, which is when the blast of the components of the explosive continues to continue its blasting process.

After a certain point, the initial stimulus no longer interferes with the reaction, and only the self-propagation of the explosive continues to continue the reaction, until all the explosive charge in our hole detonates. That's why we need to start this reaction in the best possible way, so that it remains at the highest level of efficiency.

This occurs very quickly, and the reaction will occur according to the characteristics of the initial stimulus and the explosive, which in practice, we need to consider that they can undergo several changes inside the hole (presence of water, debris, rock characteristics, etc.), and these changes can improve or worsen the reaction to the initial situation. Here comes all the need for quality control, both of the explosive and of the application conditions, so that they do not interfere negatively in this process.

Ideally, we want the best part of the reaction to occur at initiation, so that the explosive can be started in the best possible way, and thus manage to already generate its maximum velocity, and maintain it, without interference throughout the entire explosive charge.

We usually talk about the reaction of the explosive as a function of its speed, because it is easier to understand, and it is directly linked to the energy and pressure of the blast, but in fact, when saying that the explosive reacts at its maximum speed, we mean that it reacts at its maximum efficiency, which means that in addition to speed, the rates of energy release, blast pressure, gas generation, temperature rise and all blast products of the explosive will be at their highest values, according to the type and condition of the explosive.

So, in short, we can divide the blast propagation process into 4 steps:

A - The initial stimulus causes shock waves

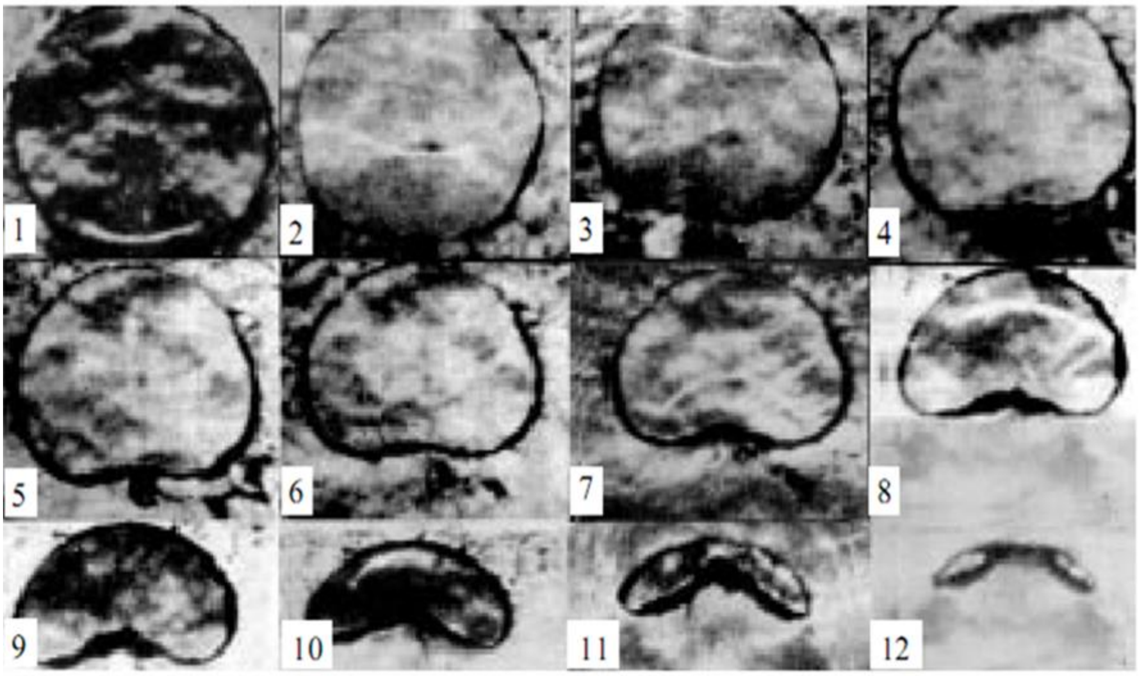
B – When the shock waves reach the microbubbles (sensibility points) they cause a compression

C – Compression of the microbubbles causes an increase in temperature and internal pressure

D – The microbubbles suffering high pressure and temperature rise break, propagating more shock waves, allowing the continuity of the process through the generation of new shock waves that intensify the action of the other shock waves already in operation.

We can consider that this process occurs in any type of explosive and in the different conditions of application of the rock blast, both in the open and underground, where some are more representative, such as long holes with the explosive charge distributed inside them, up to slightly more simplistic examples, such as the blast of a load of "João de barro" to break a block of rock.

Here below, we have a record of a microbubble or "hot spot", being compressed when hit by a shock wave, where it compressed to its maximum, in frame 12.



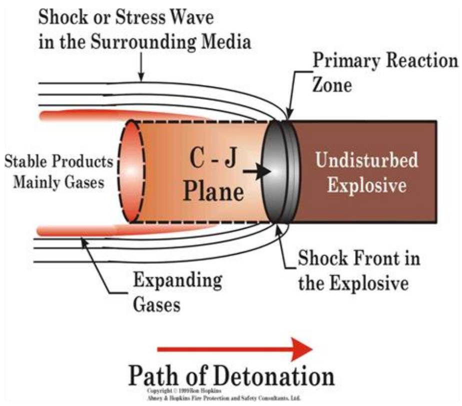
And as we said, at this moment in frame 12, when the bubble is compressed to its maximum, we have an increase in pressure and temperature to the point that it cannot withstand it and that is when it will burst, generating a shock wave, caused by the rapid expansion of the gas inside the bubble.

In the blast reaction of an explosive, this process occurs in several bubbles/points at the same time, and throughout the mass of the explosive, we will have bubbles in all states, depending on the moment and intensity of the shock waves that have already reached each one. of these bubbles.

Reaction/detonation zones

Thus, when we analyze the entire blast process, which occurs throughout the explosive load, after this load receives the initial stimulus and starts its reaction, that is, throughout the blast process, we can identify 3 main reaction zones of that process.

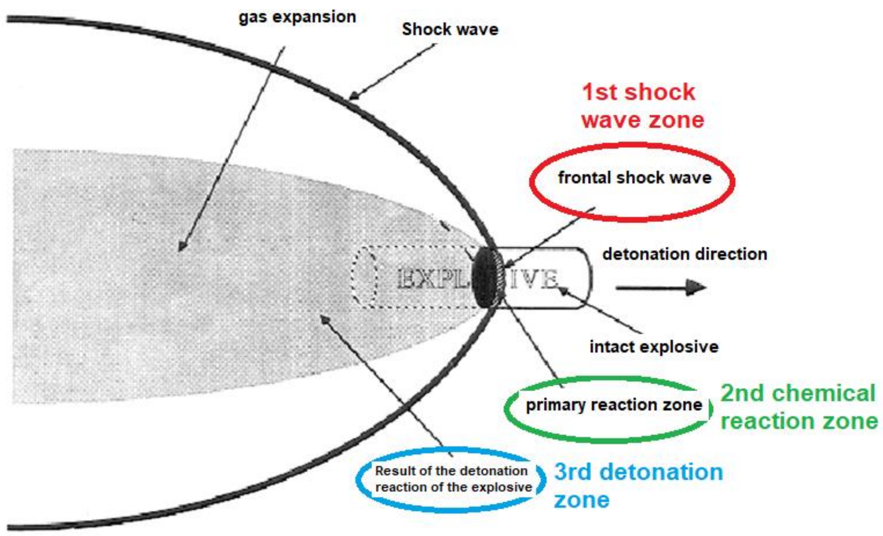
1st) The first is what we call the “shock wave zone”, which consists of the blast front, where the shock wave is reaching the explosive mass that is still intact, that is, it is when the shock wave meets with the microbubbles (sensitivity points) that have not yet been reached. Here in our figure we can say that it is precisely the limit of the beginning of the wave's contact with the explosive (beginning of the brown area in the left figure), which is where the explosive that has not yet detonated is being touched for the first time by the shock wave.



2nd) Then we have our second zone, which is the chemical reaction zone, which consists of the area where the shock wave has already passed, it is compressing the microbubbles or activating the sensitivity points, and with that some of them are breaking and others will follow soon after, continuing the process. Which we can say is represented by the gray area in our illustration on the left, also known as the “C J” plane, which is exactly where the blast reaction is taking place.

3rd) Finally, we have the third zone, which is the area where the reaction has already occurred, that is, the microbubbles have already broken and the explosive has already detonated and is generating its effects, which is its transformation into gases, which expand at high temperature and pressure. That here in our figure, it is this light red area, on the left, which is where we have the beginning of the reaction of the explosive with the rock.

Below we have another figure that illustrates the same process for a better understanding.



So during the blasting process, we can say that we have three main explosive zones, which are:

• Shock wave zone: It is the blast front, where the shock wave is propagating and reaching the still intact explosive mass.

• Chemical reaction zone: It is the area that has already suffered the shock wave and started the chemical reaction of its components:

• Blast zone: It is the area that has already carried out its chemical reaction and is already detonating.

It is important to consider that after the initial stimulus provided by the initiator, these 3 processes or zones will be present simultaneously, where they need to occur efficiently so that we have a good release of energy from the explosive, because, for example, if the wave of shock finds a part of the explosive contaminated or mixed with water, the reaction that will occur in phase 2 will be inefficient, generating a smaller amount of energy in phase 3, and this will affect the continuity of the process.

So we need to keep in mind that the entire blast process can be affected by several factors, and of course this will affect the pace and performance of our blast. So we need to understand the process well, in the same way we need to understand well what can affect it, in order to be able to control the quality and performance of the rock blast.

For today we will stop here, we will continue in the next article talking about some factors that can affect the blast process, as well as the main effects of the blast, so that in the following articles we can talk about the rock fragmentation process.

That's it folks, it's great to be able to return with our publications and we hope to continue contributing to the dissemination of knowledge about rock blasting.

I confess that this year looks like it will be very busy, but we will try our best to follow the letter with our articles, and we leave here once again the invitation to those who wish to contribute with some articles or comments, because as we always say, the space will always be open.

Please comment and share, so that we have increasingly safe and quality detonations!!!

May 2023 be a year of good health, happiness, success and good detonations!!!

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