Analysis of the wreck of *Kirishima*

By Robert Lundgren with Anthony Tully
Edited by Tony DiGiulian

On November 13, 1942, the Japanese battleship *Kirishima* was sunk in the first US-Japan battleship duel of World War II. Her wreck laid undisturbed until discovered by Dr. Bob Ballard in 1992 as part of a joint expedition by the U.S. Navy and The National Geographic Society to locate and document the shipwrecks in Iron Bottom Sound of the ships lost during the battles for Guadalcanal. Dr. Ballard's exploration of *Kirishima*'s wreck was cut short by a near-fatal mishap which made it necessary for Dr. Ballard to make an emergency ascent. As a result, only nine minutes of video was taken of the *Kirishima*'s wreck with very little of the port side viewed and only a small portion of the aft starboard side. Charles Haberlien, a naval historian with the U.S. Naval Historical Society, was with the 1992 expedition and used the expedition's ROV to film some of the debris field in 1992, but this was very limited and incomplete. This and other data gathered during this exploration was used as part of my 2009 essay "*Kirishima* Damage Analysis."

A second expedition, mounted by Paul G. Allen's company Vulcan Inc., revisited the wreck on January 31, 2019. This exploration was conducted by Vulcan Inc.'s research ship R/V *Petrel* under the command of Robert Kraft and Paul Mayer. Anthony Tully, working with the researchers on *Petrel*, contacted me in regards to my earlier essay to discuss points of interest about the wreck. *Petrel* had recently re-located the *Kirishima* wreck while covering a search area looking for *Kirishima*'s sister-battleship *Hiei* (which was indeed found for the first time) which had been sunk two days earlier by US forces. Mr. Tully had been using my 2009 articles to evaluate film of the *Kirishima*'s wreck and determine where to look for damage. Mr. Tully was kind enough to get my updated 'wish list' of points to look for if a second visit by the ROV occurred but, based on my article, he had already conveyed a distilled summary to the crew of the *Petrel* of key damage points to seek. As it happened, the dives already completed would be the only ones that took place during this expedition. However, the photographs taken during the expedition were enough to answer a host of questions. This new essay incorporates this knowledge and corrects errors in the 2009 essay.

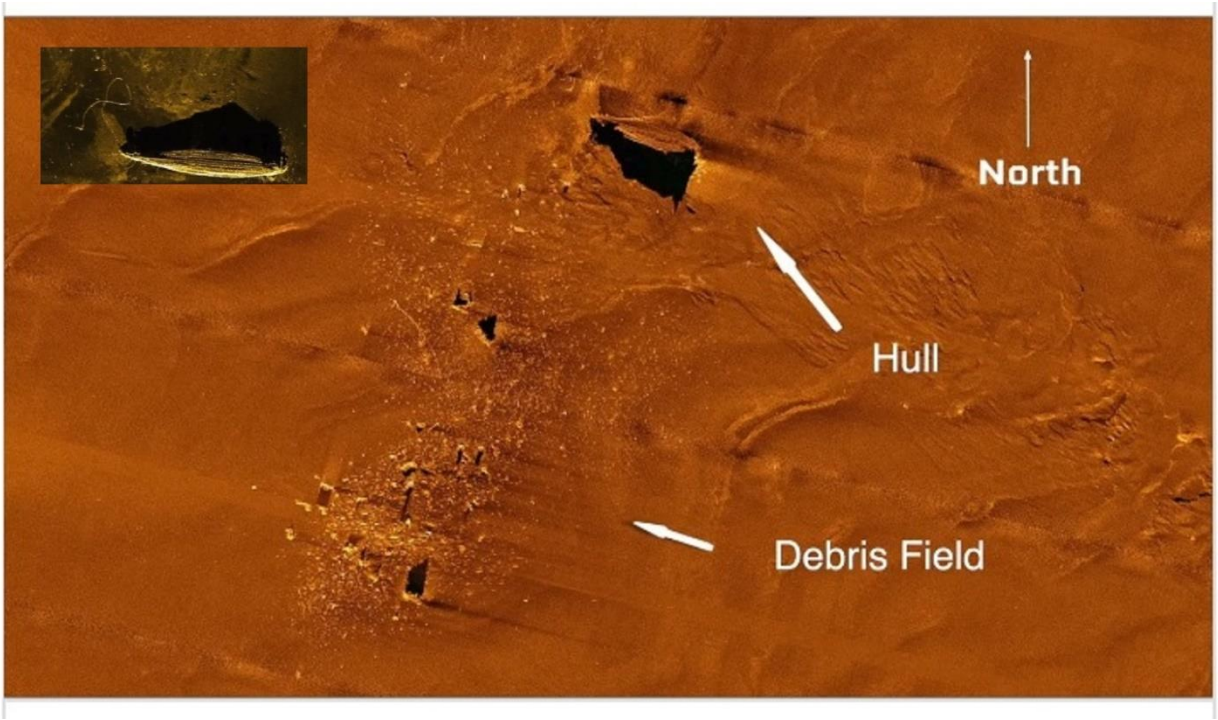

Figure 1 - Sonar image of *Kirishima* wreck site and debris field

Figure 1 shows that the stern of the wreck is pointing west at approximately 285 degrees and the hull break points east at approximately 105 degrees. When I first saw the sonar image, I was surprised. The debris field was not where I expected it. I had assumed the debris field was largely concentrated where the bow break was. This clearly shows it is not and that the debris originates at the point of her stern and drifts south roughly at 195 degrees for what appears to be approximately 3-4 ship lengths. The sonar also shows that *Kirishima* did not break evenly. Her port side is longer than her starboard side. Anthony Tully believes that the large objects producing shadows in the debris field may be part of her pagoda superstructure and her bow. Unfortunately, the 2019 expedition schedule did not permit the ROV to film this area and positive identification of these structures will require a future visit.

Charles Haberlien in 1992 described the debris field as thousands of twisted broken unidentifiable parts. When intact *Kirishima* was 720 feet 6 inches long and she had 314 frames with each frame 2.29 feet apart. *Kirishima*'s port side is now approximately 545.02 feet long or 166.12 meters and broken at frame 76. Frame 76 was the leading edge of Turret 'B' barbette but the barbette structure has been totally obliterated. *Kirishima*'s starboard side is approximately 503.8 feet or 153.55 meters long at frame 94. This is approximately where number 3 casement gun was located under her pagoda superstructure. The way the debris field is distributed shows that *Kirishima* suffered her break up when she was still vertical and

before she reached the bottom 1,200 meters down. Based on these sonar images the debris field extends approximately 600-700 meters from the stern section.

At present I believe she may have broken up as she sank and approximately 500 meters from reaching the bottom. With her vertical orientation at the time that would place her bow at a depth of roughly 550 meters. In my 2009 articles I wrote that her four main gun turrets fell out after she capsized on the surface. I believe now that this is incorrect. I wrote that because at the time I believed all battleships gun turrets were only secured in their barbettes by their own weight like the *Bismarck* as an example. I have since learned this assumption is incorrect. Many battleships had retaining clips. For example, the US battleships of the *North Carolina*, *South Dakota*, and *Iowa* classes all have turret retaining clips.

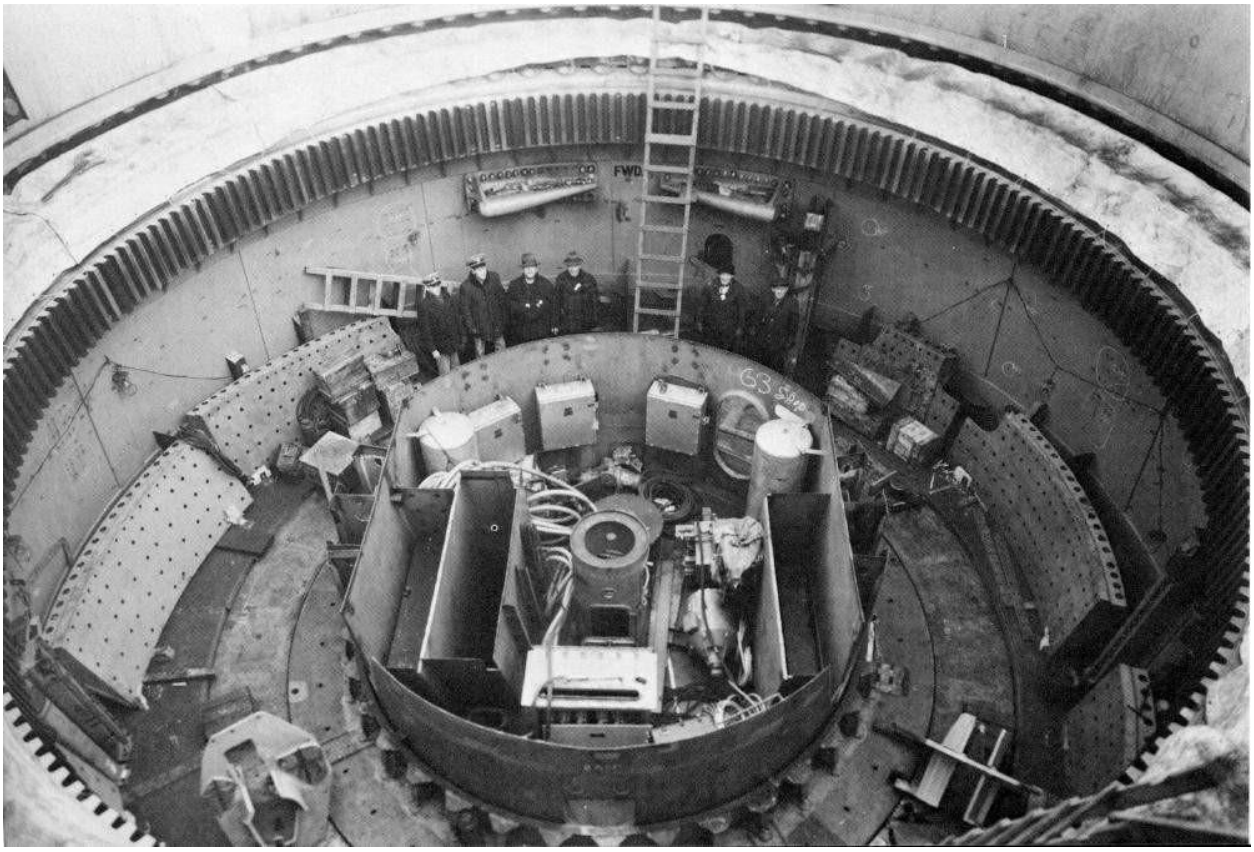

Figure 2 - The barbette structure of U.S.S. *New Jersey* (BB-62)
Philadelphia Naval Shipyard photograph

Figure 2 is published in at least "Battleship *New Jersey*" by Paul Stillwell and is also at http://www.NavSource.org. Here is the NavSource caption for this photograph:

> *The New Jersey's (BB-62) No. 2 turret shell deck is seen prior to the installation of the turret rotating assembly. The turret hold-down clips are leaning against the foundation*

bulkhead, and the central column and powder hoist trunks are visible. The two cone shaped pieces are the training stops for the turret rotation. The canvas cover protects the cones rollers on the lower roller track.

In this photograph you are looking at the lower stalk, which consists of the two (Turrets I and III) or three (Turret II only) shell decks and the powder room deck. The lower stalk was assembled inside the stool before the turret framework was lowered into it. The turret framework consisted of the gun house, pan floor and electric deck levels. Once the turret framework was in place, it was welded/bolted to the lower stalk – so that the entire stalk rotates together – and the hold-down clips were bolted into place on the turret framework. Even if the clips were not in place, I'm not certain that the turret would fall out should the ship became inverted, unless it was almost completely inverted, as the stalk might jam inside the stool and prevent the assembly from falling out.

The primary function of these retaining clips is to prevent the turrets from upsetting – "jumping the tracks" if you will – should the ship be rolling or pitching heavily in a seaway while firing. That they hold the turrets in place should the ship capsize and sink is simply a by-product of their primary purpose.

It is unknown at this time exactly how British and Japanese turrets were retained, but the authors are fairly certain that some mechanism must have been used based upon the evidence that the great majority of turrets on wrecked ships are still in place in their stools.

Figure 3 – Turret 'A' on the inverted wreck of *Nagato*
Photograph copyrighted 2015 by Pete Mesley of Lust4Rust and used here by his kind permission

As can be seen in Figure 3, the Japanese battleship *Nagato* capsized after sinking at Bikini and her turrets are still in their barbettes. Turrets 'A' and 'D' remain suspended above the seabed as the wreck rests on the roofs of turrets 'B' and 'C' and divers can swim under the other turrets. These turrets have had 70 plus years to fall out, yet they are still snug in their barbettes. In addition, the twelve turrets on the battleships *Fuso* and *Yamashiro* have not been located on the sea floor although both battleships have capsized. The simplest explanation is that all twelve turrets are still in their barbettes and are buried under their wrecks. The aft turrets for *Hiei* and the aft turrets for *Kirishima* have also not been discovered in their debris fields, with again the simplest explanation being that they remain in their barbettes and are now buried in the sea bottom. So, I now feel I made an error in my 2009 articles to say that they had fallen out.

Had the turrets fallen out, this would have removed a key ingredient as to why *Kirishima* suffered an underwater detonation. That the barbette structures have been destroyed leads me to believe that they are the center of the detonation. More on this below and in Appendix 1.

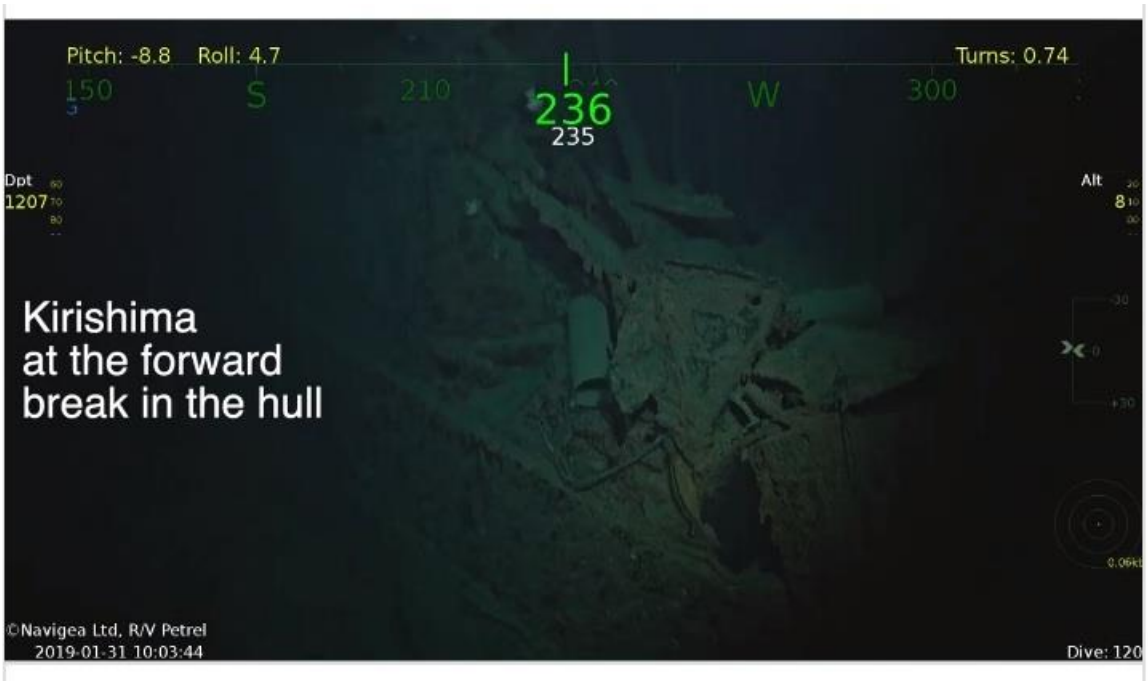

Figure 4 - Starboard hull break showing secondary powder casings

Figure 4 shows *Kirishima* at her forward hull break with secondary powder casings which are still on the wreck. This tells us that we are at her secondary shell powder magazine. There are thousands more in the debris field along with main powder casings. This was well documented by Charles Haberlien in 1992 and I have seen this film and can vouch for this description. Many of the powder casings are crushed, torn and flattened, some with one end popped open, others intact. No projectiles have been discovered by either the 1992 or 2019 expeditions. More importantly, I believe in *Kirishima*'s case that what we are seeing is the total consumption of all or nearly all projectiles stored in the forward shell rooms which includes both the main and the secondary projectiles. *Kirishima*'s bow is not just separated, it has been obliterated. Propellant powder cannot burn underwater and it has not been consumed, as much of it is still present in the debris field. Therefore, the powder was not the source of the explosion.

Since 2009 I learned partly from critics of that article that surface ship watertight hatches are not really designed to be very strong. I was not aware of this and believed they were much stronger than they are, but I now understand that a typical hatch would probably reach its crush depth before the entire ship left the surface. With the 2019 evidence, it now seems clear by the way her hull was broken that the barbettes are at the center of the explosion. Turret 'A' is completely gone and the explosion inside Turret 'B' started on the port side and moved to starboard, blowing out the starboard side plating. Her side plates in this area are largely cracked at the joints, but the lighter TDS plates are peeled back around her sides and keel, showing us evidence of a massive internal explosion.

In 2009 the only overly-sensitive explosives I was aware of on *Kirishima* were the secondary 6" projectiles. The bursters of these are made with Japanese picric acid (*Shimose*) and are very sensitive to shock. This at the time was my thinking in that something had to produce a massive shock wave that could detonate the secondary projectile magazines. I do believe this did happen, but now, I do not believe this was due to implosion as the ship sank, but as a result of the shock wave of a hydrogen gas vapor explosion produced by a thermite fire within both forward barbettes. Implosion is still a large part of the wreck on both *Kirishima* and *Hiei* but we are mainly seeing it in the TDS systems and keel tanks, not around the magazines.

I estimate the bow section that remains begins at frame 40 forward to frame 1 which is where her chain locker begins just in front of Turret 'A' barbette. Lt. Ikeda placed a hit on the chain locker. I believe the hull was weakened in this area but also a 16-inch projectile smashing into the chain locker and exploding would naturally cut large sections of chain loose. Clearly the wreck shows some of her chain spilled out over her stern and draped across her propellers. However, the amount of chain in my opinion that has spilled out does not look like that was her entire amount of chain for three anchors. This is speculation on my part. If the bow section is discovered and eventually filmed confirmation of up to four hits may be expected but it would not surprise me that all three anchors are still in place and a large amount of her remaining chain is still in the locker.

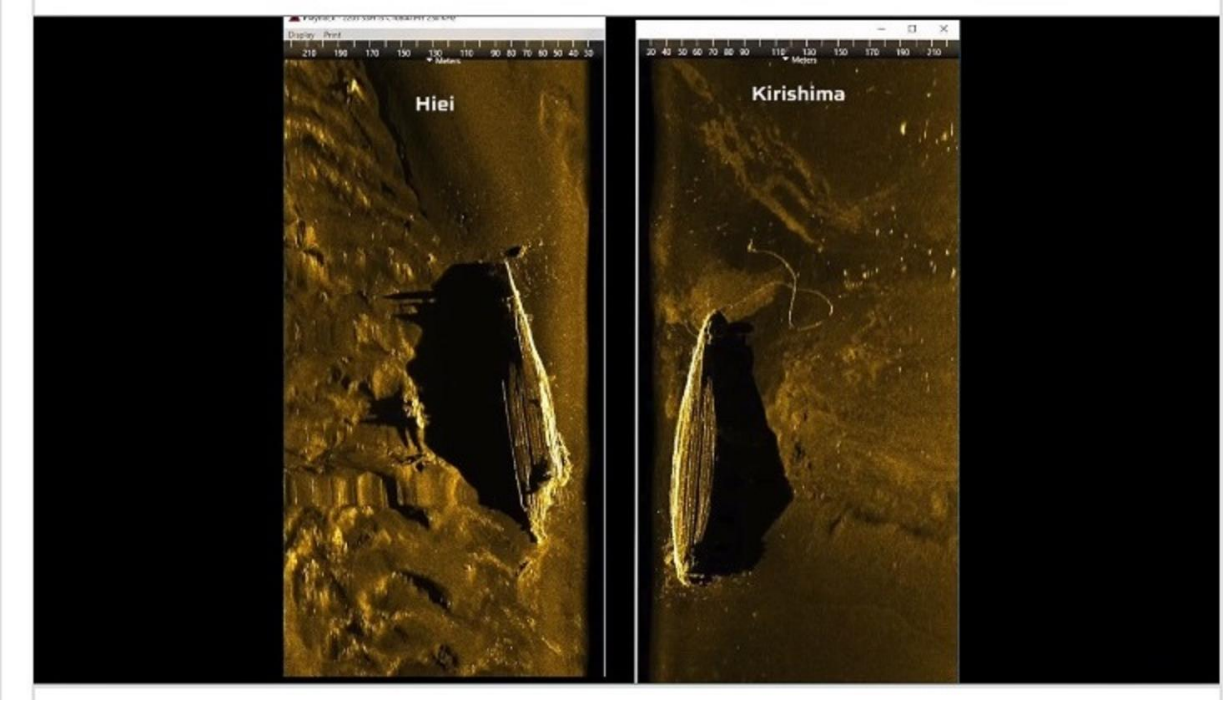

Figure 5 – Comparison of *Hiei* and *Kirishima* wrecks

On the *Petrel*'s Facebook page there is a comparison photo of the *Hiei* and *Kirishima* wrecks, shown here as Figure 5. The anchor chain which drapes across *Kirishima*'s stern is

clearly visible in the sonar image. A comparison of the two wrecks is potentially useful. The wreck of *Kirishima* is more intact. *Hiei* ripped apart at approximately frame 156 on her starboard side, which is where her aft mast is located and just forward of her aft stack, and then she ripped diagonally to approximately frame 132 or where her forward stack was located. The stern section of her wreck is slightly shorter than *Kirishima*'s and is now approximately 361.82 feet long. Both the port and starboard aft 5-inch 40 caliber guns were discovered in her debris field along with a large section of her aft mast that housed a 25 mm gun mount and its ready ammunition resting on her hull. What is striking about her sonar image is the lack of debris around her stern. There is a debris field 500 meters from her stern but not enough to make up for the missing bow section. Photos of her hull break show her plates are all bent down in one direction.

Hiei was not observed when she sank. She was last seen settling by the stern. I believe she eventually lost transverse stability and capsized and then began to sink by the stern. This forced her bow up, so she attempted to lift her bow out of the water and possibly due to torpedo damage her sides and keel were not able to withstand that much unsupported weight and the plates all bent down and she ripped in half. Once the stern section freed itself from the bow, it sank rapidly stern first. The bow section had to re-start the sinking process and drifted away, but I do believe *Hiei* has an intact bow section still waiting to be discovered and it should be reasonably close to the stern section, quite possibly within two or three miles of the stern. However, since the forward section was not located or any obvious remains found, this must remain conjecture.

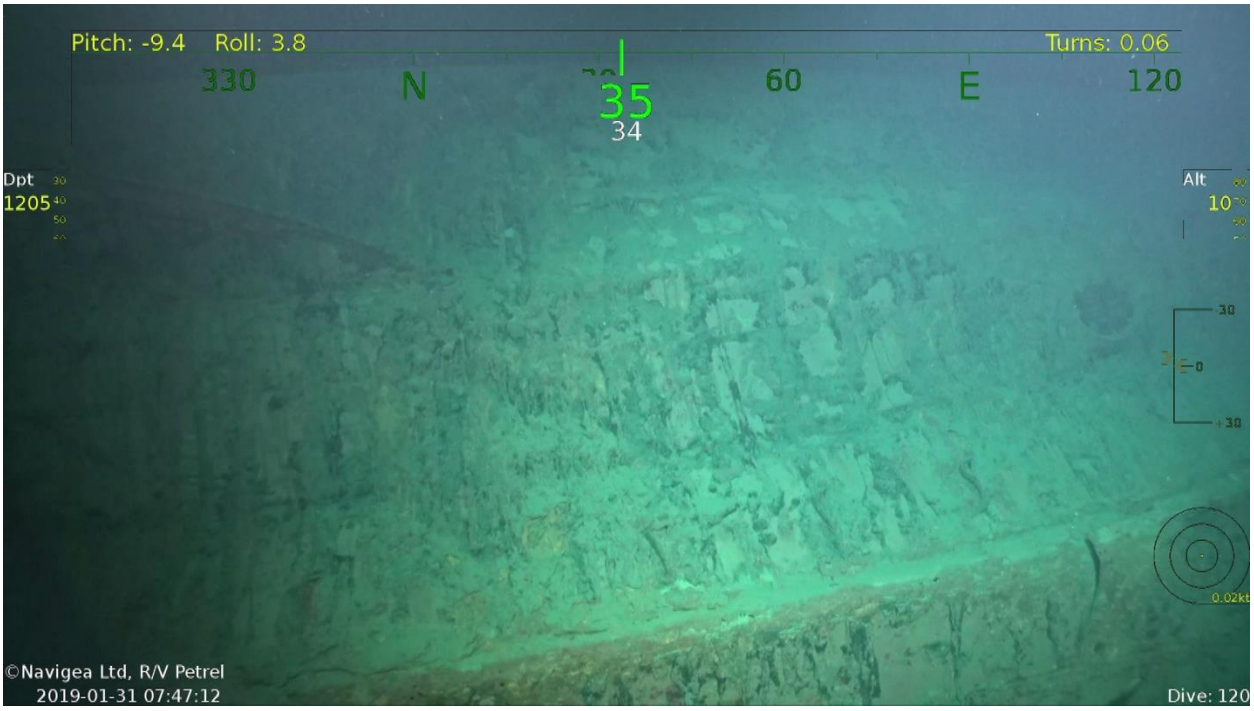

Figure 6 - 16-inch shell hit Frame 76 port side

The sequence of screencaps from the *Petrel*'s ROV revealed a dramatic picture. As the *Petrel*'s ROV approached *Kirishima* on January 31, 2019, her massive hull suddenly appeared from the abyss. They had approached on her port side very close to where the bow was broken. Subsequently the ROV would make a complete circuit of the wreck, passing down aft, behind the stern, and back up starboard side to the forward break. As a result, documentation of the main wreck was close, if not quite, complete. The edge of the bilge keel in Figure 6 above marks the location at about frame 80. Immediately one of Lt. Ikeda's underwater shell hits appear just forward of the bilge keel at approximately frame 76. This was a surprise because I thought all hits were on the starboard side. The only time that *Kirishima* presented her port side to U.S.S. *Washington* was at 0107 when *Washington* fired her last salvo. *Washington*'s logs do not list the exact time of this salvo, meaning that the time could have been 0107.00 or 0107.59, but *Kirishima* was observed circling to port by 0107. This helps with the timing of any port side hits discovered.

This hit is directly into her main powder magazines. Lt. Ikeda also placed two hits through the barbette structure of Turret 'B'. The exact timing of these two hits is unknown. He also placed two hits through Turret 'A' barbette, and we have dramatic testimony from *Kirishima*'s flooding control officer flooding the number one powder magazines. Both forward turrets were listed in *Kirishima*'s action report as being smashed. Now the wreck can no longer confirm the barbette hits as the forward barbettes no longer exist. I firmly believe based on all the primary documentation and witness accounts that the four barbette hits all took place. A

hit directly into her 'B' turret powder magazine might lead one to suspect a H.M.S. *Hood* type magazine explosion event to soon follow. This did not happen. There are several possibilities. The first and most likely is that when this hit was scored Turret 'B' had already been destroyed and her magazine had been flooded as a precaution. The second possibility is that while the damage shows an entry hole, we do not know if the projectile detonated. Like the projectile from U.S.S. *Massachusetts* that found the secondary magazine of the French battleship *Jean Bart*, the projectile may have been a dud. A third possibility is a U.S.S. *Boise* type incident in that the projectile worked as expected but the water coming through the hole flooded the magazine and prevented a major deflagration.

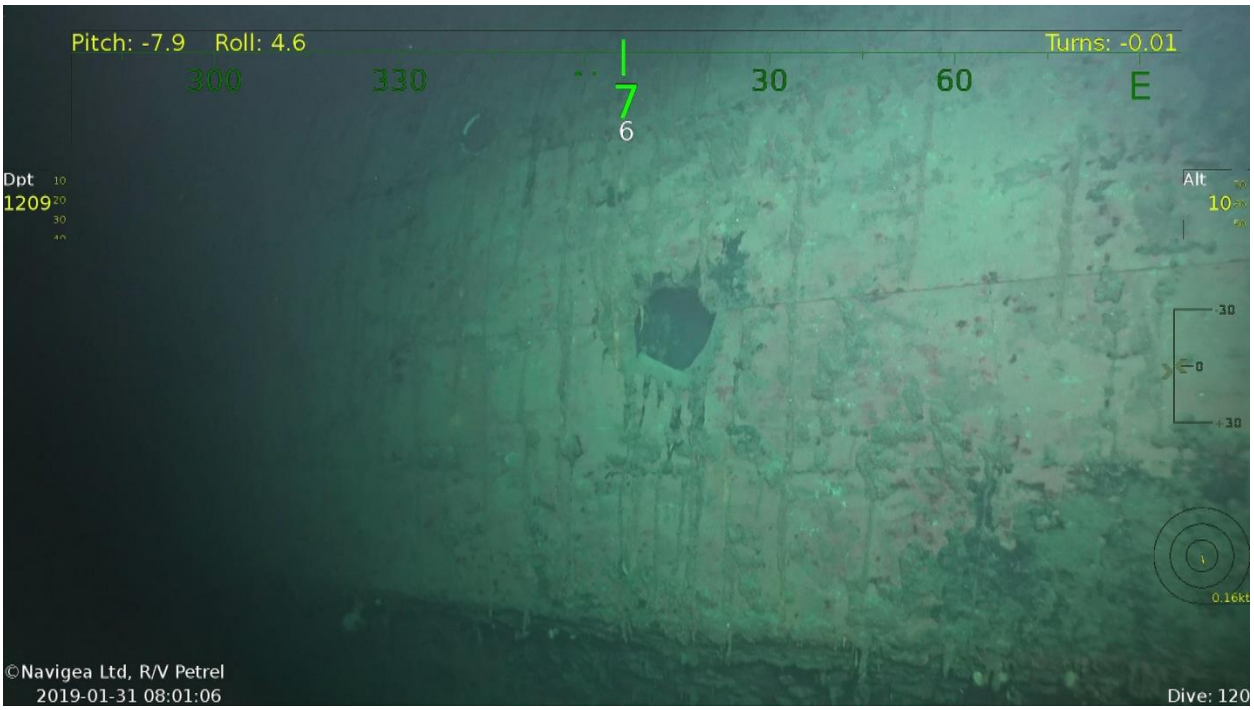

Figure 7 – 16-inch shell hit Frame 100 port side

The *Petrel*'s ROV now moves along the port side moving aft and quickly discovers another below-the-waterline hit at approximately frame 100 in Figure 7. This impact in my 2009 article I had on the starboard side destroying her forward starboard hydraulic pump room. However, the hit actually occurred on the port side and destroyed the port side hydraulic pump room. The ledge is the top edge of the torpedo bulge and marks the top edge of the main armor belt. This impact would also have taken place with *Washington*'s last salvo at 0107 and occurred simultaneously with the hit at frame 76. This is important because *Kirishima* lost the use of turrets 'C' and 'D' due to a loss of hydraulic pressure. Initially, when the H.M.S. *Invincible* class was built, British battlecruisers were fitted with only two hydraulic pump rooms to operate four main battery turrets. It was discovered that these two pump rooms could not operate all the turret functions simultaneously, so subsequent British battlecruiser and

battleship designs of the World War One era received three or four pump rooms. When the Japanese *Kongō* class was designed, they received three pump rooms, two on the starboard side and one on the port side. *Kirishima*'s action report states specifically that her main battery was silenced due to a lack of hydraulic pressure for turrets 'C' and 'D'. The only hit fully filmed in 1992 lined up with the aft starboard hydraulic pump room. So, this matches the primary data and *Kirishima* was able to fire up until 0110, three minutes after this hit was scored, when she fired her last main battery salvo, scoring a hit on the *South Dakota*'s Turret III, and then *Kirishima*'s aft turrets go silent, unable to train or elevate.

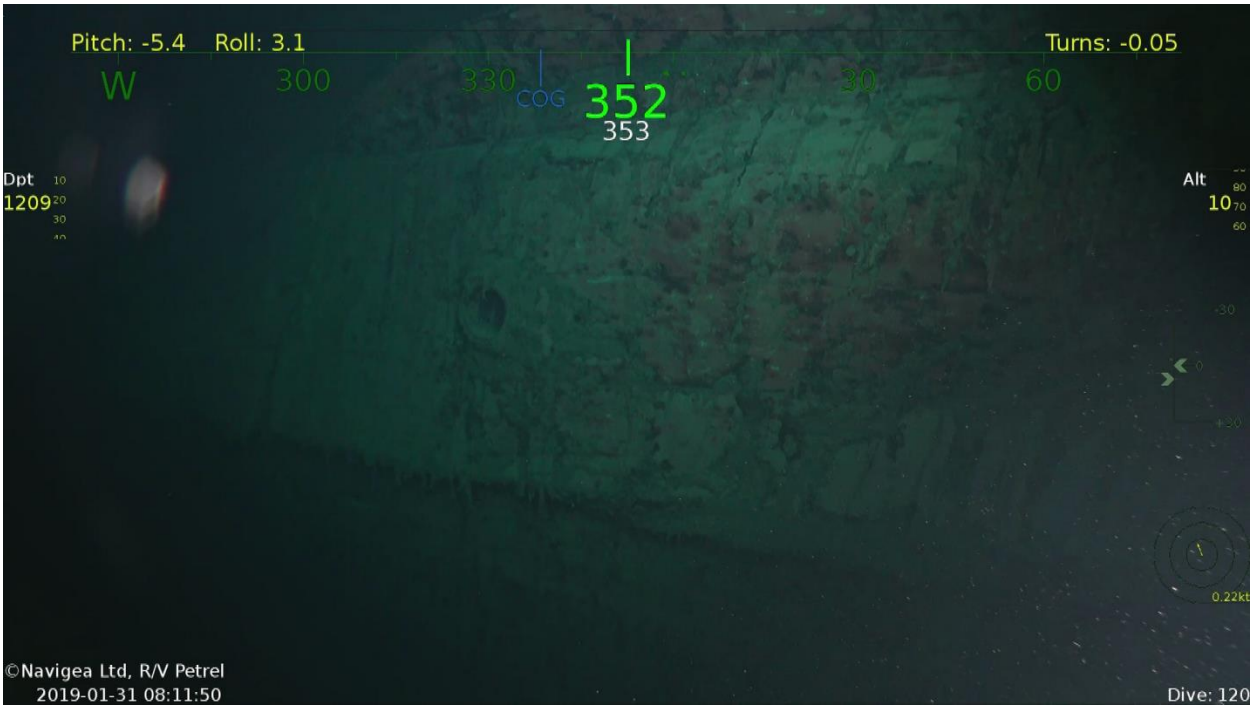

Figure 8 - Drainage pipe installed in 1937

The *Petrel*'s ROV now moves along the port side moving aft and another weird hole appears in Figure 8, but this is not battle damage; it is in fact part of her design. Its location is just aft of Turret 'C' and the bilge keel ends at frame 234 which crucially helps us locate where we are on the hull. This pipe is some form of drainage. It was installed in 1937. The pipe's exact purpose is not known. It appears to be related to draining the bilge; perhaps for cleansing purposes. There are two undocumented 5-inch shell hits just aft of this pipe in the 9 mm plate that made up her outer torpedo bulge.

Figure 9 - *Kirishima* seen in 1937 with drainage pipe circled
U.S. Naval Historical Center Photograph

In Figure 9, the unusual apparent drain hole is circled here on the port side. It helps mark the location and this drain pipe was part of her design. It is not on the starboard side.

Figure 10 - Two unknown 5-inch shell hits Frame 234

Anthony Tully first spotted two hits just aft of the pipe in the side shell as shown in Figure 10. The shells detonated on impact indicating a nose fuze projectile. Lt. Ikeda had listed a hit outside the engine rooms and I believed this was on the starboard side in my 2009 article. The hit listed was of major caliber and clearly these are not 16-inch shell hits but represent two unknown 5-inch shell hits again probably being scored around the 0107 time frame. As the ROV moved aft we approach the port side outer shaft at frame 258.

Figure 11 - Frame 258 outer port shaft shows blast damage as it enters her hull

I believe that Figure 11 is the one of several under-keel detonations that struck *Kirishima* aft. This damage I believe also plays a critical role in why *Kirishima* will circle to port despite her rudders being jammed to starboard. At 0106 *Kirishima* is attempting to withdraw and has turned away so her stern is directly pointing at *Washington*. I believe this damage was scored around 0106 with *Washington*'s second to last salvo. Mutltiple shells land near her stern and this one detonates under her keel blasting the plates that covered her shaft as it enters the hull peeling them back.

Before *Kirishima* sank her records say she only had one operational engine room and that was the inboard port engine. I had assumed in 2009 based on witness accounts the loss of the engine rooms was due to fires being swept down through her forced draft ventilation. However, the new data suggests another and stronger possibility. Upon seeing more of the damage that her stern took, I believe now that her propellers were significantly damaged and this forced the crew to shut these engines down. It also has the advantage of explaining

another reported source of damage. A non-contact explosion over this area that can blast the steel plates away are very likely to rupture the shaft seals that lead back to the engine room. Lt.Commander Kyūshichi Yoshino received reports of flooding in the engine rooms and was worried about the crew at these locations.

The *Kirishima*'s engine rooms did not take a direct hit so what was the source of the reported flooding? I believe the shaft seals for this shaft are ruptured and while her pumps could easily control such flooding, turning the shaft probably did not help, so this engine I believe was shut down either as a precaution or to help control flooding.

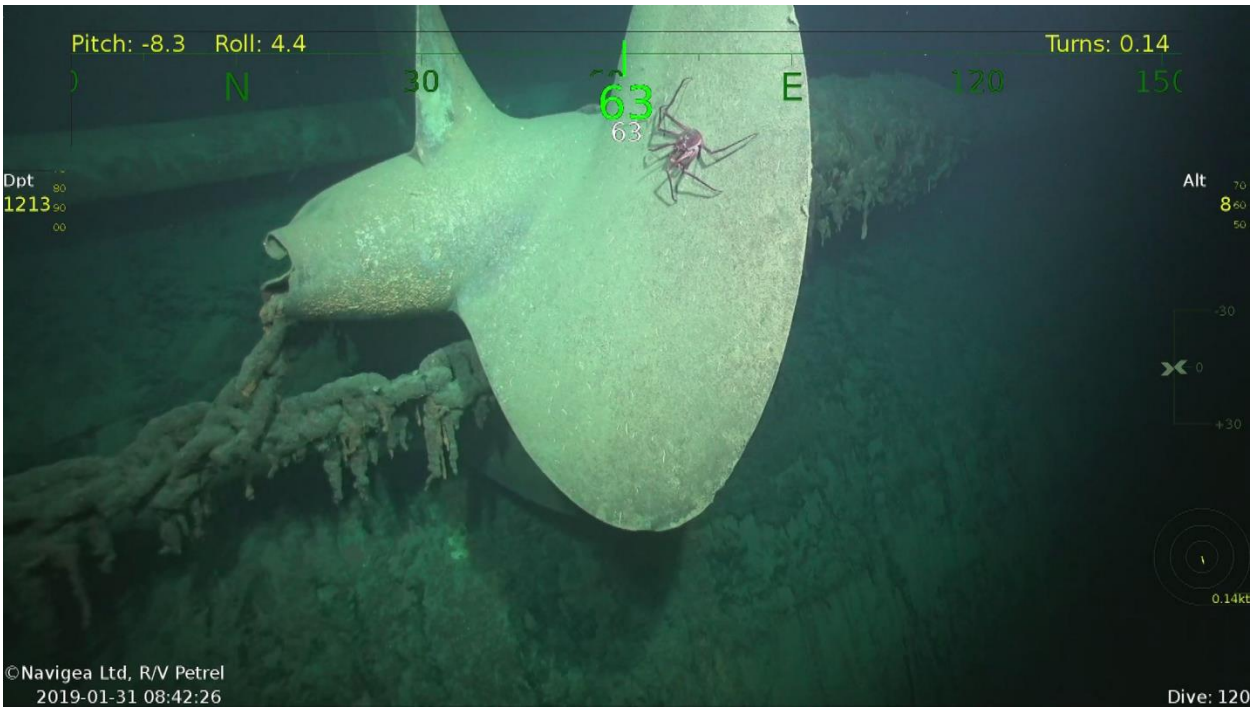

Figure 12 - Outboard port propeller remains in excellent condition

The condition of the outboard port propeller in Figure 12 is pristine, as a crab makes *Kirishima* his new home. What is important is to compare this to the condition of her starboard propellers. This is what an undamaged propeller blade should look like. The propeller tip has imploded slightly. To give the reader a sense of scale, the propeller diameters on *Kirishima* are 3.658 mm (12.00 ft) for the outer pair and 3.734 m (12.25 ft) for the inner pair.

Figure 13 - Inboard port propeller is also undamaged

Figure 13 shows the inboard port propeller which was the last one known to be operational before she sank. The heavily jammed port rudder is now coming into view on the left side of this photograph. The propeller tip has imploded due to water pressure but the propeller itself is largely undamaged. The anchor chain when she broke apart now drapes over this entire area. There is a fragment hole in her hull at the bottom edge of the photo just a bit to the left of the anchor chain.

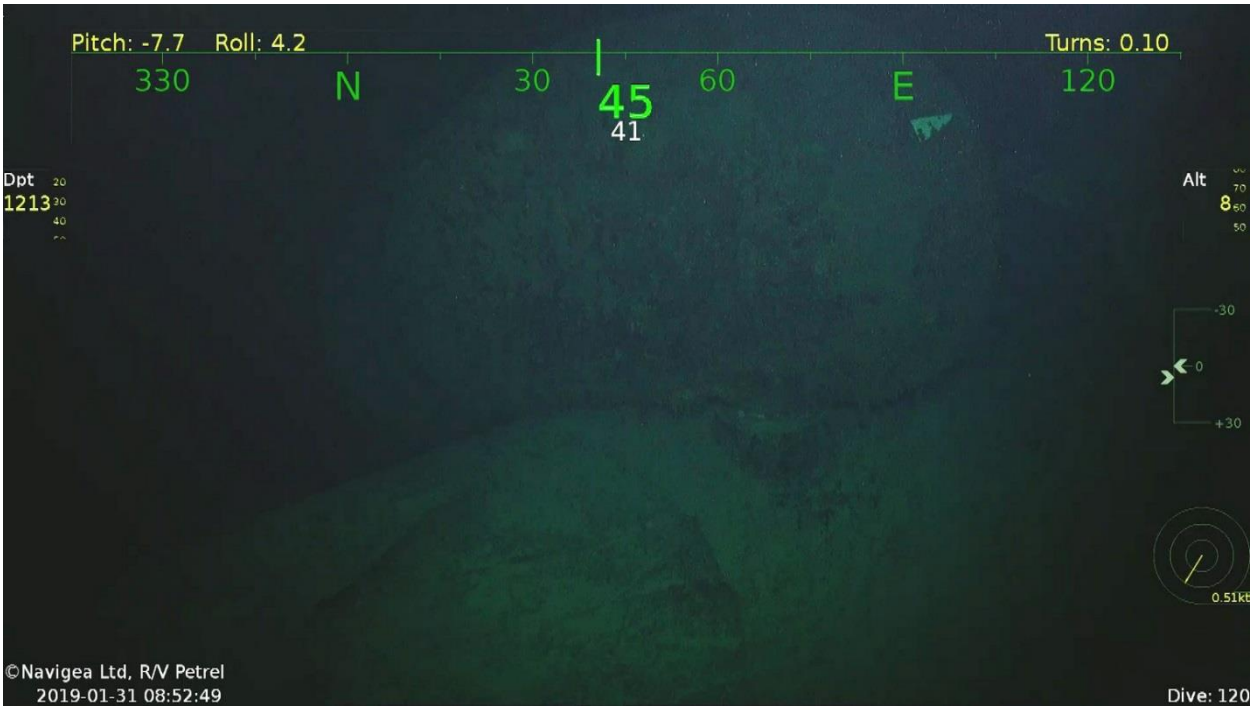

Figure 14 - Blast pattern from exploding 16-inch shell just aft of the port rudder

Figure 14 shows a blast impression on the hull just aft of the port rudder. Her keel is slightly pushed up and a shell detonating at this location would force the port rudder hard over to starboard which is exactly what we see. I believe this damage is scored around 0106 as soon after she was observed circling to port which will present her port side to the *Washington* for the 0107 impacts. The port rudder is jammed to starboard at approximately 85 degrees. The starboard rudder is approximately turned to about 10 degrees starboard. Normally the rudder can't turn more than 30 degrees off center.

Figure 15 - *Kirishima*'s stern with bent keel

What remains of *Kirishima*'s stern was a surprise because it somewhat contradicts the image planted in my mind from a painting of the upturned wreck in the Ballard book. In that painting, the fantail was depicted as cleanly broken off and suggested that most of the admiral's cabin was gone. As Figure 15 shows, this is not the case at all. In fact, her entire keel is still attached. The fantail is buckled, not severed. She is missing the side plates for the last two or three frames or 4-6 feet, but her admiral's cabin is still largely intact.

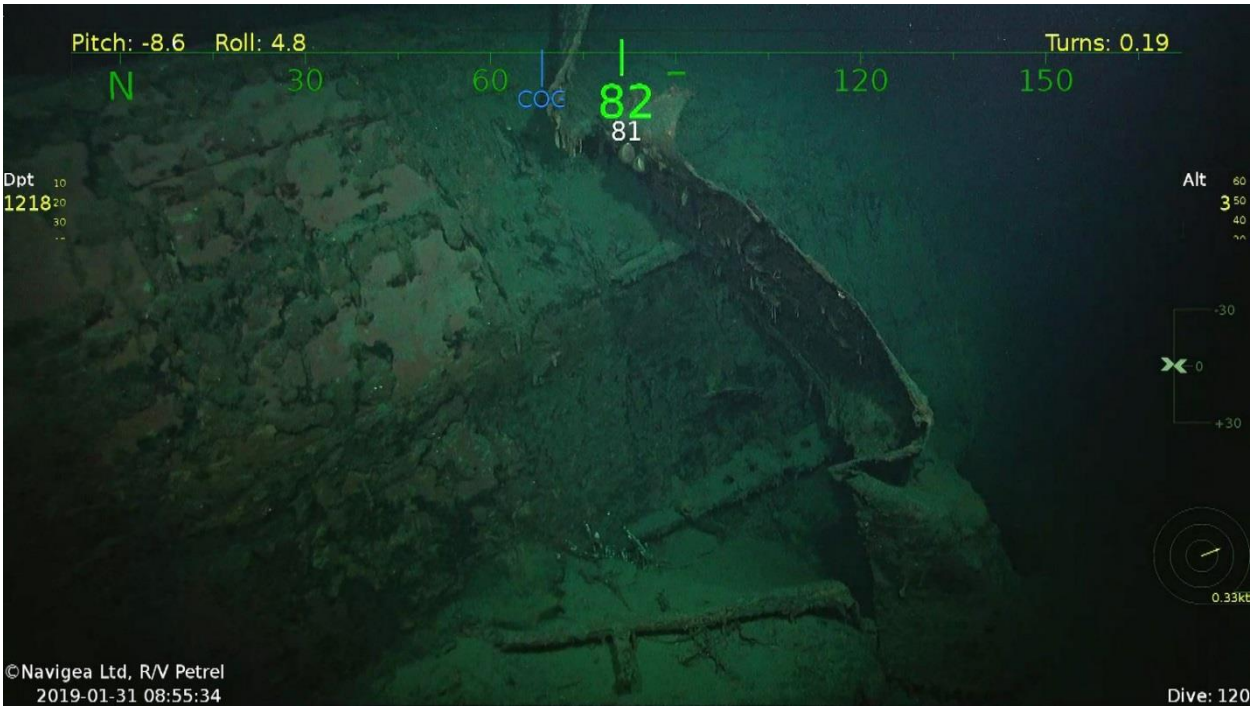

Figure 16 - Exit hole damage from two 16-inch shells seen on the port side aft of her rudder post

Lt. Ikeda placed three hits on the stern, and I have them a bit more forward in my 2009 article. They all hit aft of the rudder posts. I believe there are two hits one at frame 302 and 305 and both these shells detonated and are the two hits Lt. Cdr. Hank Seely observed from the *Washington* at 0105. I believe a third hit at frame 311 and simply went straight through the hull shattering the side plates at the very stern tip. The entry holes for these shells are not visible on the starboard side being now in the mud. The stern is not that wide and when the shells detonated, they sent their heavy nose pieces through the port side shell plating and peeled back her outer shell from within. The dark shadow at the mud line is a big hole which penetrates the other side of the plate right at the mud line. Fragment holes can be seen higher on the hull. When *Kirishima* sank stern first she landed on her stern tip and this bent her keel slightly but shattered the damaged side plates which removed the direct evidence of a 16-inch shell hit at the tip. I do believe it is a combination of shell damage and how she sank as to why the stern tip side plates are missing. I do believe it is incorrect to describe her stern as missing. The keel is still completely attached although it is bent due to her landing on it.

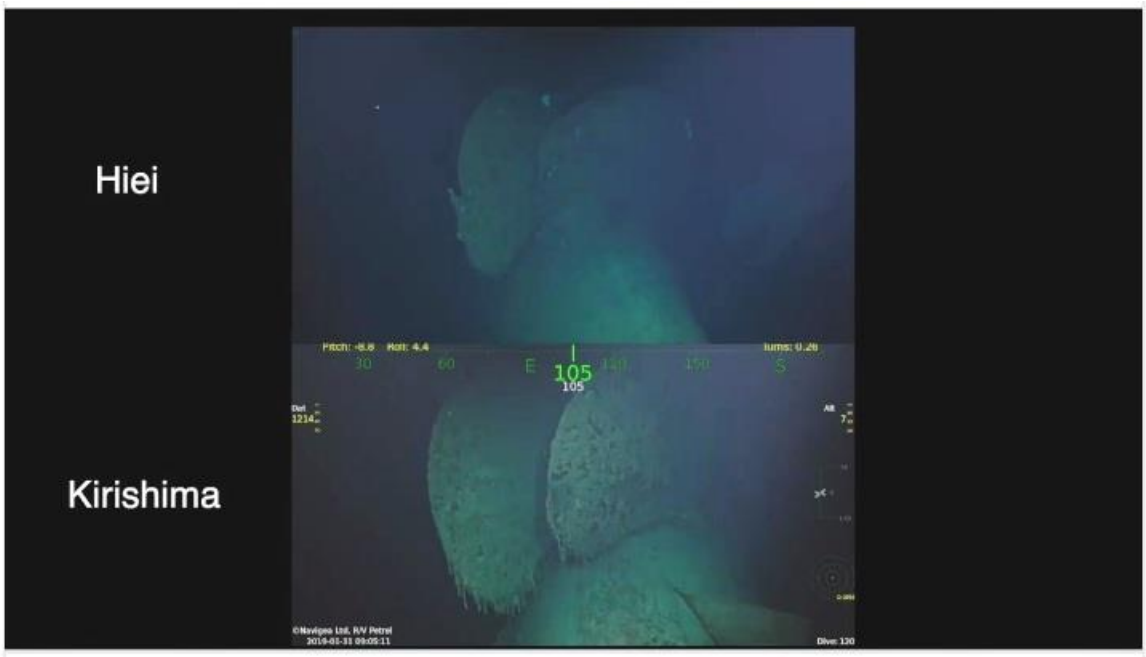

Figure 17 - Comparison view of *Hiei*'s and *Kirishima'*s rudder jams

Figure 17 is from the *Petrel*'s Facebook page and is a comparison of *Hiei*'s and *Kirishima*'s rudder jams. This photograph shows both *Hiei* and *Kirishima*'s rudder jams are almost identical. This damage in fact left *Hiei* crippled and making wide clockwise loops. While it makes perfect sense for a ship with her rudders jammed hard to starboard to circle to starboard, *Kirishima* did not. As the *Petrel*'s ROV moved to the starboard side an explanation became more evident.

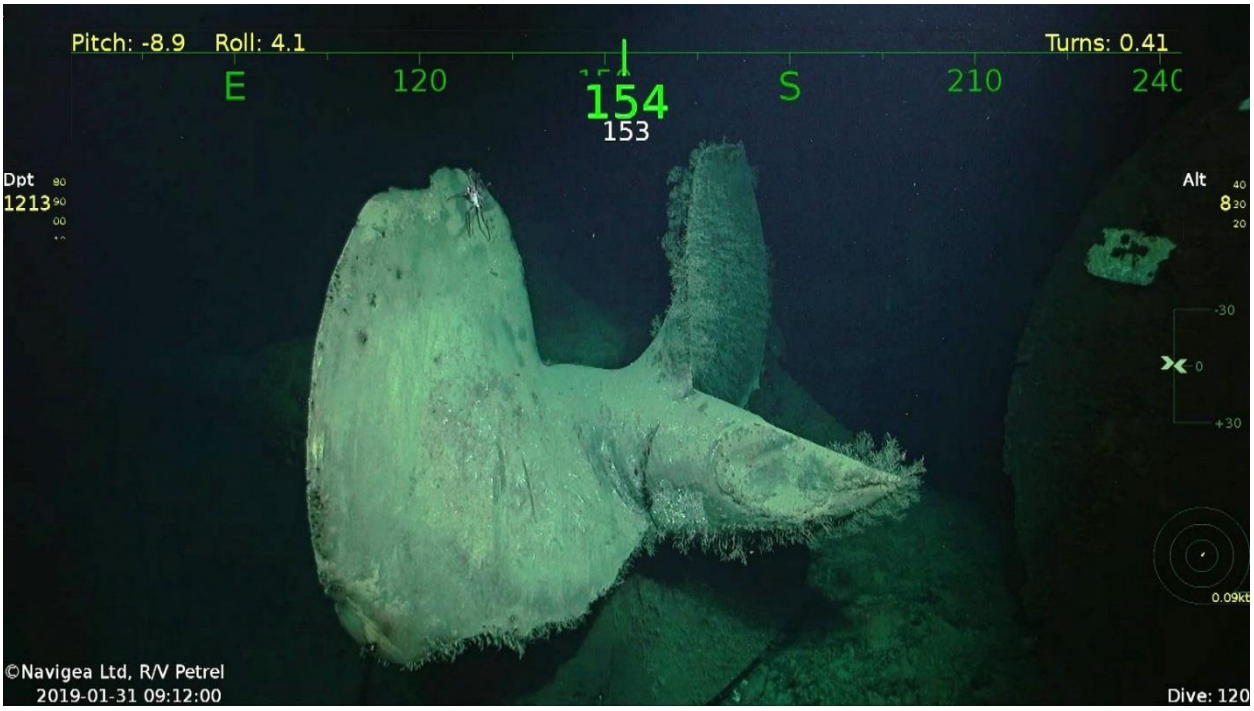

Figure 18 - Inboard starboard propeller

Figure 18 shows *Kirishima*'s inboard starboard propeller which is badly damaged and the bottom edge of one blade is broken. This propeller is also bent, chipped and dented.

Figure 19 – Outboard starboard propeller

The *Kirishima*'s outboard starboard propeller and it too is badly bent and misshaped. It is quite dramatic to compare the port side propellers and the starboard side and just how badly damaged the starboard side propellers are.

Figure 20 - Correction in 2009 article concerning hit behind chain and possible hit by USS *Helena*

In reviewing Figure 20, I need to correct an error in my 2009 article. In that article, I believed that I saw a hit behind the chain hanging off the outer shaft propeller blade. The 2019 film also produced a dark circle that at first glance looks like it might be a hit, but it turned out to be a shadow from the propeller blade itself. There is not a hit at this location. However, just to the left of the chain there is a shell impact between the 120-150 closer and below and to the left of the 150. Anthony Tully's eagle eyes spotted this impact and it appears to have been made by either a 5-inch AA common or this could be the hit she received on November 12 from the *Helena*. It is not a 16-inch shell hit and it is not part of the 17 x 5-inch projectiles listed by Lt. Ikeda for the night of November 15. I believe this is the hit she received on November 12 though I can't be 100 percent certain. It is either the hit from the *Helena* or an undocumented 5-inch shell hit from the *Washington*.

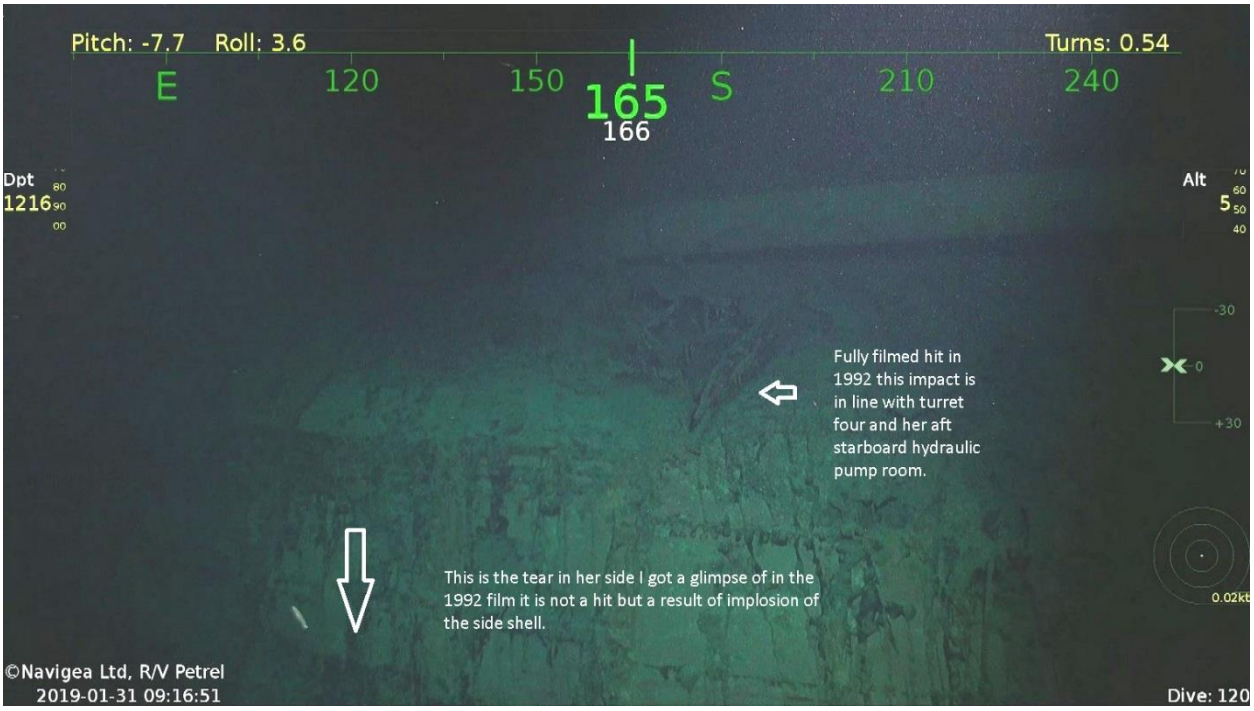

Figure 21 - Fully filmed 16-inch shell hit in 1992 and tear in her side shell due to implosion

The ROV moves forward and in Figure 21 captures the hit already noted in 1992 at frame 265 that is in line with Turret 'D' and the starboard aft hydraulic pump room. In the same picture is the tear in her side that seemed to be battle damage. Instead it now appears that this damage is a result of her torpedo bulge imploding.

Kirishima's sides and keel are badly deformed due to implosion. The ROV moves up the hull and discovers another hole on the other side of the outboard shaft. It could be a separate hit, but I believe it is an exit hole from the projectile that impacted just on the other side of the shaft. This hit which I believe occurred at 0105 may be one of the most damaging impacts that *Kirishima* withstood this night. At 0102.30 the *Washington* reports "Cease Firing" as given by control on receipt of an erroneous report that the target was sunk. She resumes fire at 0104 and this salvo was observed to straddle *Kirishima,* but no hits were observed. By 0105 the *Washington* and *Kirishima* was almost perfectly broadside to each other. These two holes line up perfectly so if this hole represents an exit hole it tells me the shells trajectory was very close to normal in relation to her target. That places the time at around 0105. Lt. Cdr. Hank Seely would not be able to observe this hit because it was below the waterline and would have thrown up a splash, but he did observe two hits on the stern with this salvo.

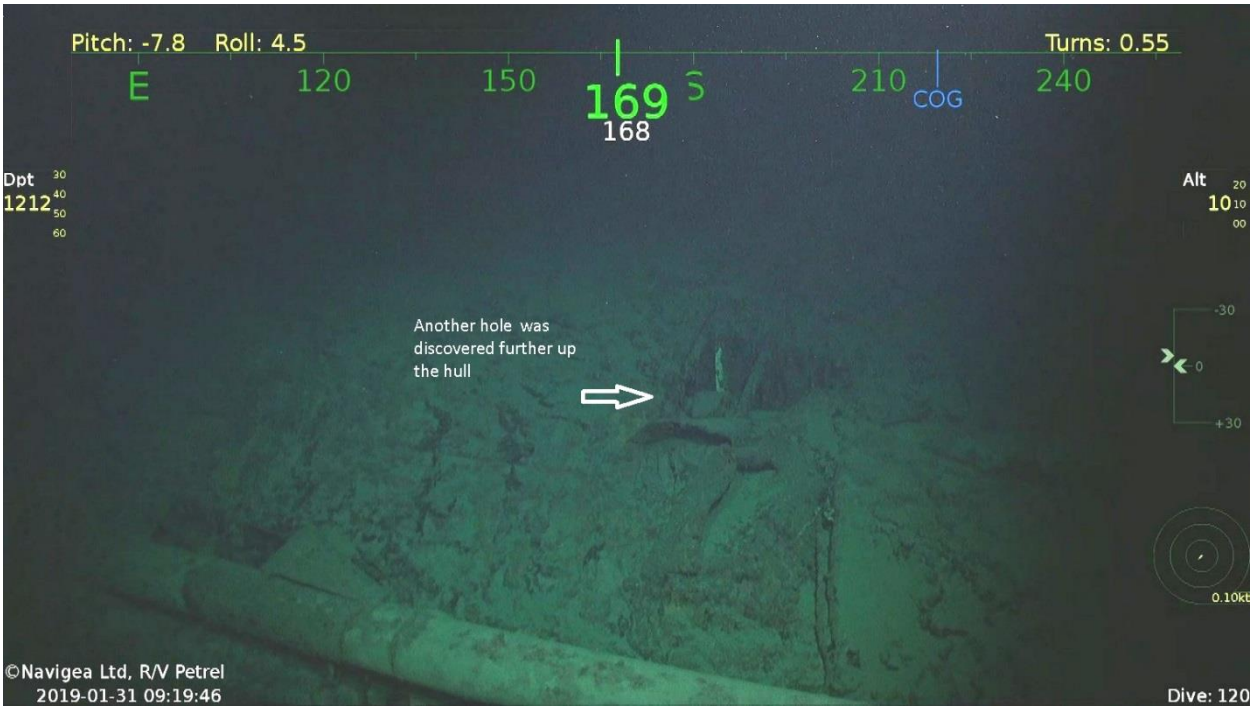

Figure 22 – Exit hole of 16-inch shell which then explodes under her keel, damaging both starboard propellers

I believe the shell impacted the aft starboard hydraulic pump room near the floor of that compartment which resulted in its immediate flooding. The impact would have begun fuze action within the projectile, but the shell exited the hull before the fuze activated due to the shape of *Kirishima*'s stern and then detonated under her keel. The resulting explosion warps both starboard propellers so that they are no longer stable and the crew was forced to shut down both starboard engines. This means that by 0106, when the next salvo jams her port rudder and disables her outer port shaft, she only has one remaining engine available, her inboard port engine that was now blocked by the port rudder turned almost sideways. The reason *Kirishima* circled to port was due to not applying any thrust on her starboard side and minimal thrust on her port which was directly blocked by the jammed rudder. Therefore, *Kirishima* swung to port despite her rudders being jammed to starboard. It was the propeller damage that had made turning the shafts unstable that forced her crew to shut them down and it does match the limited documentation that she only had a single operational engine before she sank. This is one of three projectiles that would have detonated under her keel at her stern. The shock damage would have been significant.

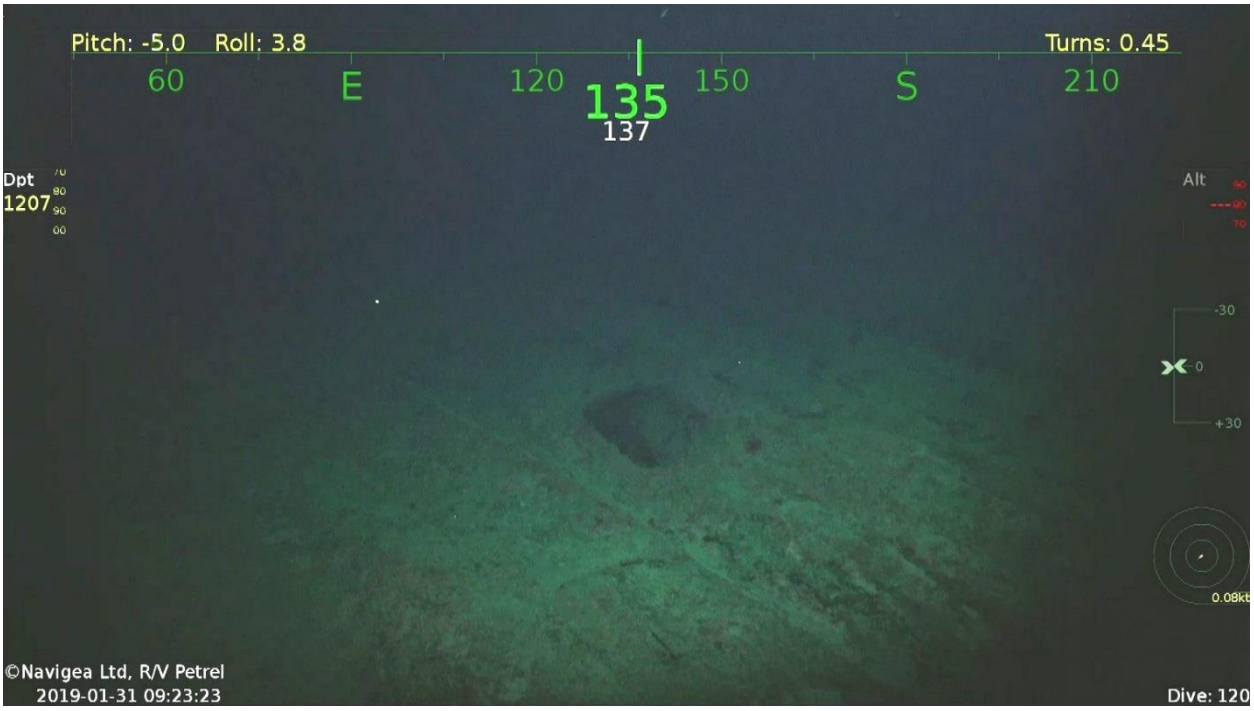

Figure 23 - A sea chest on *Kirishima's* keel

The ROV moves up onto her keel and in Figure 23 we find a sea chest and that her keel has suffered implosion damage roughly at the position of Turret 'C'. Unfortunately, by having the ROV move up onto the keel at this point, the 2019 survey misses the round object the hull is resting on that was seen in the 1992 survey. This object may be the bottom of Turret 'C' or it may instead be another part of her structure. The ROV moves back over her side and we see in Figure 24 and Figure 25 that her sides are badly deformed due to implosion as her TDS (Torpedo Defense System) has been crushed inboard.

If the round object does turn out to be Turret 'C' then it still does not change my position at all that the forward turrets remained in place until the detonation. In fact, it helps support it. When *Bismarck* capsized at the surface, all her turrets fell out immediately. All four were found in her debris field. In 2009 that was my expectation for all battleships but in reality, *Bismarck* is the exception, not the rule. HMS *Royal Oak* capsized yet retained all her turrets, the same is true for HMS *Repulse* and HMS *Prince of Wales*. The sonar images of *Hiei* are so good that her detached 5"/40 AA mounts were easily spotted in her debris field, yet not a single 14"/45 caliber turret from her has been located in her debris fields. The same is true for the debris fields for *Fuso, Yamashiro* and *Kirishima*. When large, heavy objects like a battleship turret do fall out, they produce good-size impact craters on the sea floor, but none have been seen in the sonar images of these wrecks.

HMS *Audacious* was designed at almost the same time as *Kongō* and her 13.5" turrets are to a very similar design. When she capsized after being mined in 1914, 'B' magazine

exploded and demolished the bow, knocking 'A' and 'B' turrets off the ship. The wreck now lies upside down on the seabed. However, the three after turrets, 'Q', 'C' and 'D', did not fall out during her fall and remain inside their barbettes under the wreck.

At this time, I am not certain what is the round object under *Kirishima*, but in 2009 I thought it might be Turret 'C'. If it is, then she did not lose this turret until she had started to impact the bottom and this impact shock dislodged the turret only for the wreck to immediately land on top of it. This means the aft turrets also suffered a massive shock wave from the detonations quickly followed by the impact shock of the wreck hitting the sea floor. So, with my new line of thinking, the round object may still be Turret 'C' or it could be another part of her structure. If it is indeed Turret 'C', it actually demonstrates that the turrets stayed in their barbettes all the way down and she did not lose them at the surface when she capsized before sinking. The debris fields would need to be more fully examined in a future expedition in order to confirm this theory.

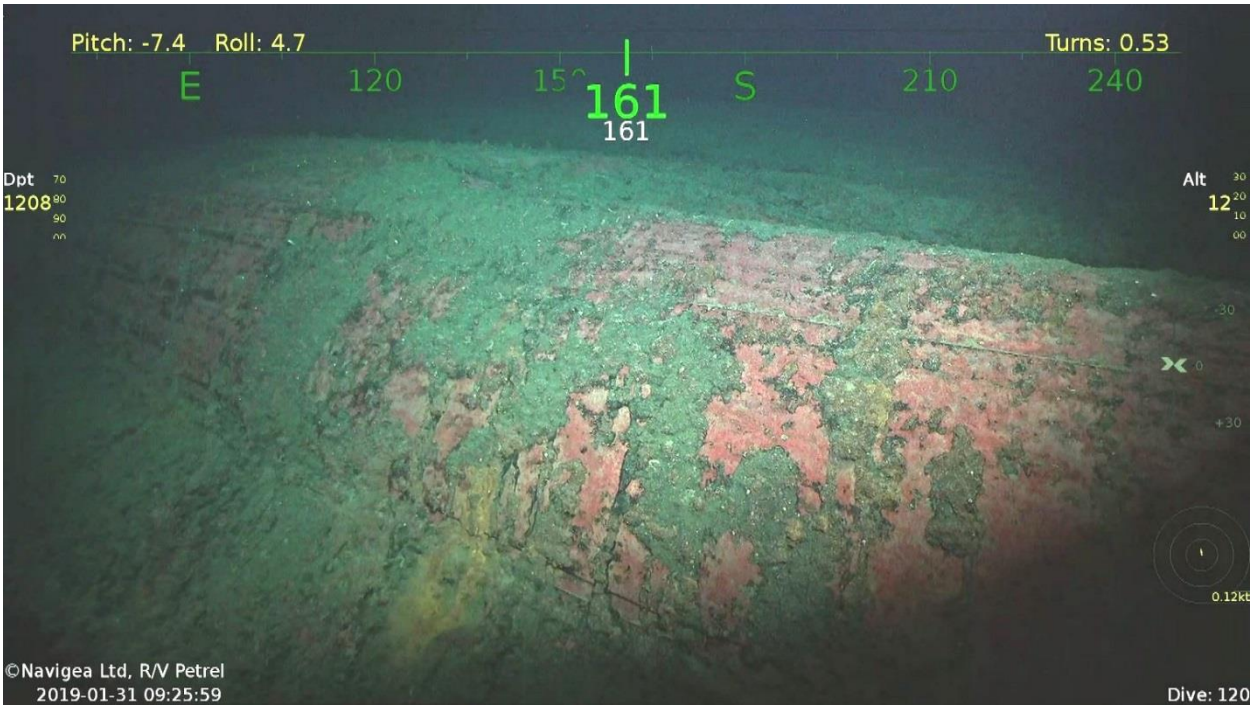

Figure 24 - Signs of implosion along *Kirishima's* keel

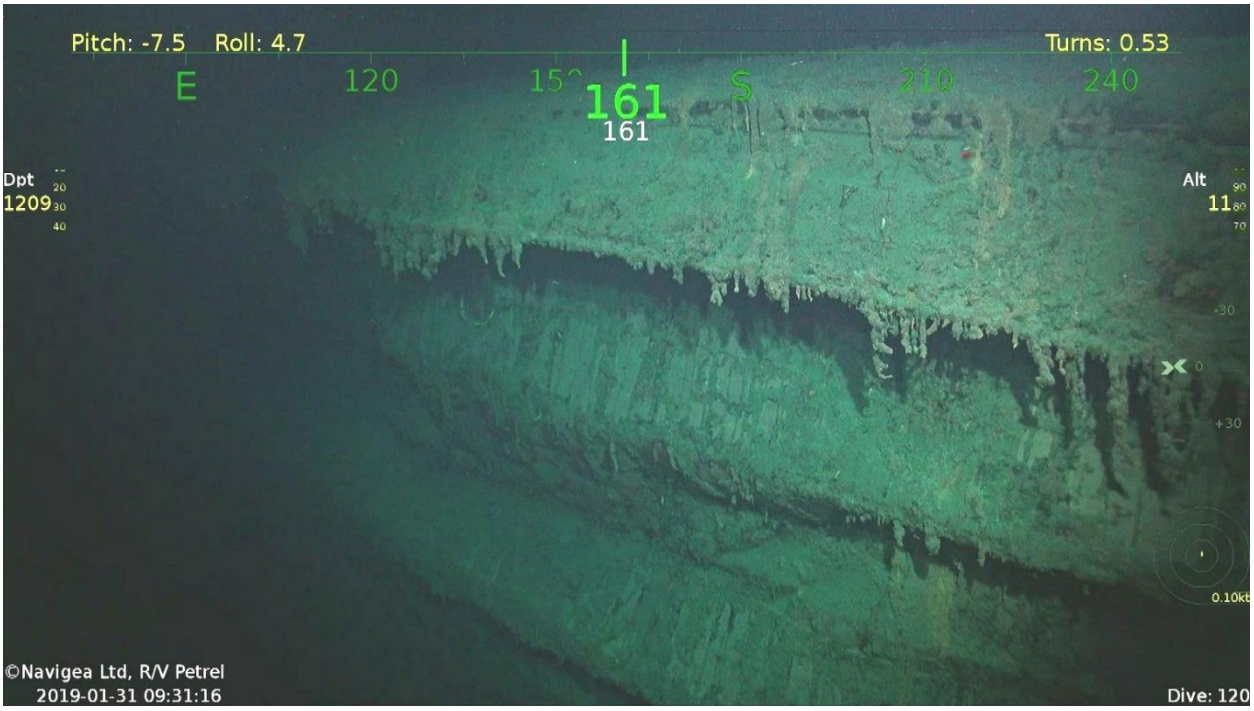

Figure 25 - Signs of implosion along her side shell on *Kirishima's* starboard side

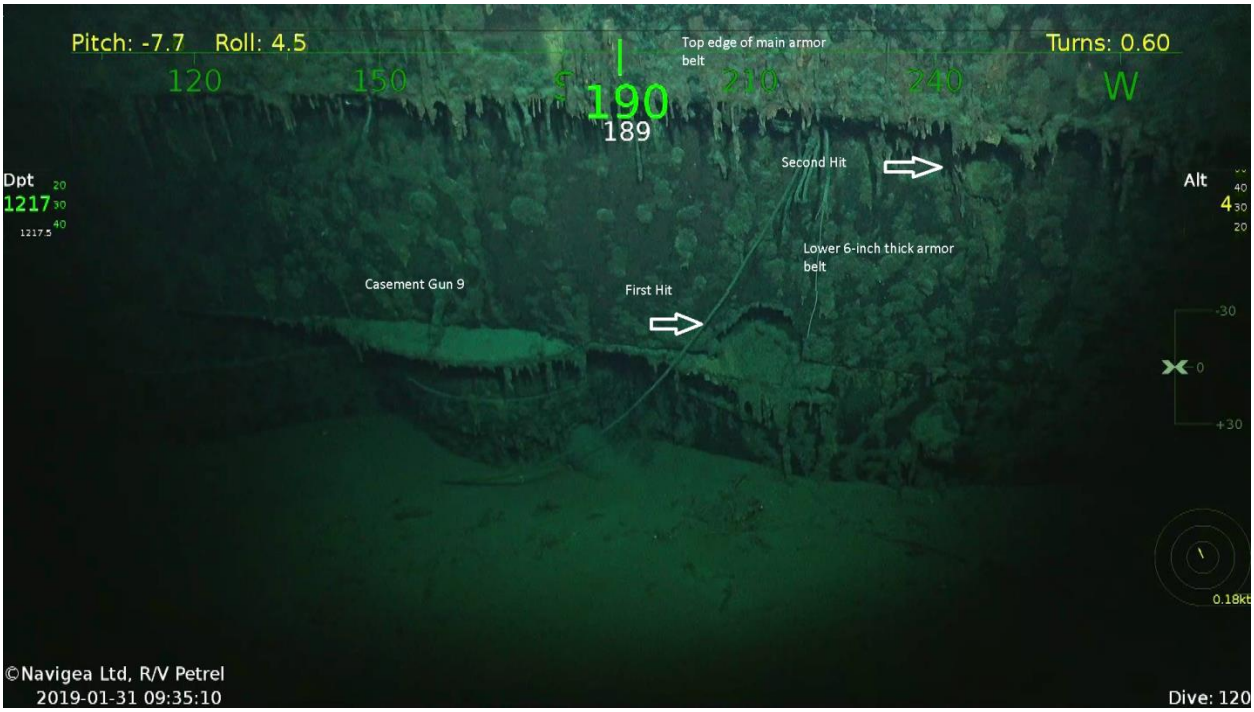

Figure 26 - Casement gun S9 showing two 16-inch shell hits through lower 6-inch VC plate

Then the first casement mounts are seen in Figure 26, which was a great surprise, because I thought they might be buried in the mud. The *Petrel*'s Facebook page shows casement gun S9 and one hit is easily seen but it is packed with mud. The second hit is harder to see as the top edge of the TDS hides it a bit and it too is now filled in with sediment. I wonder if both holes were filled by the damage control teams with a wooden plug before she sank. I have many photos of shell damage and the damage control teams sealed them with wooden plugs. Now the wood has rotten into sediment which is why they are plugged?

The plate these holes are in is 6-inches thick VC armor. The projectiles would have entered her main deck level just below the upper deck which housed the casement guns. These projectiles would have detonated close to amidships and threaten her aft secondary magazines. I believe these hits were scored on the *Washington*'s third salvo at 0102. Lt. Cdr. Hank Seely observed hits amidships from this salvo. Then Lt. (jg.) Kobayashi heard a report through voice pipes about fire in aft secondary battery casemates. The XO Commander Koro Ono ordered the aft magazines flooded and soon came a report via voice pipe confirming that this measure had been successfully executed.

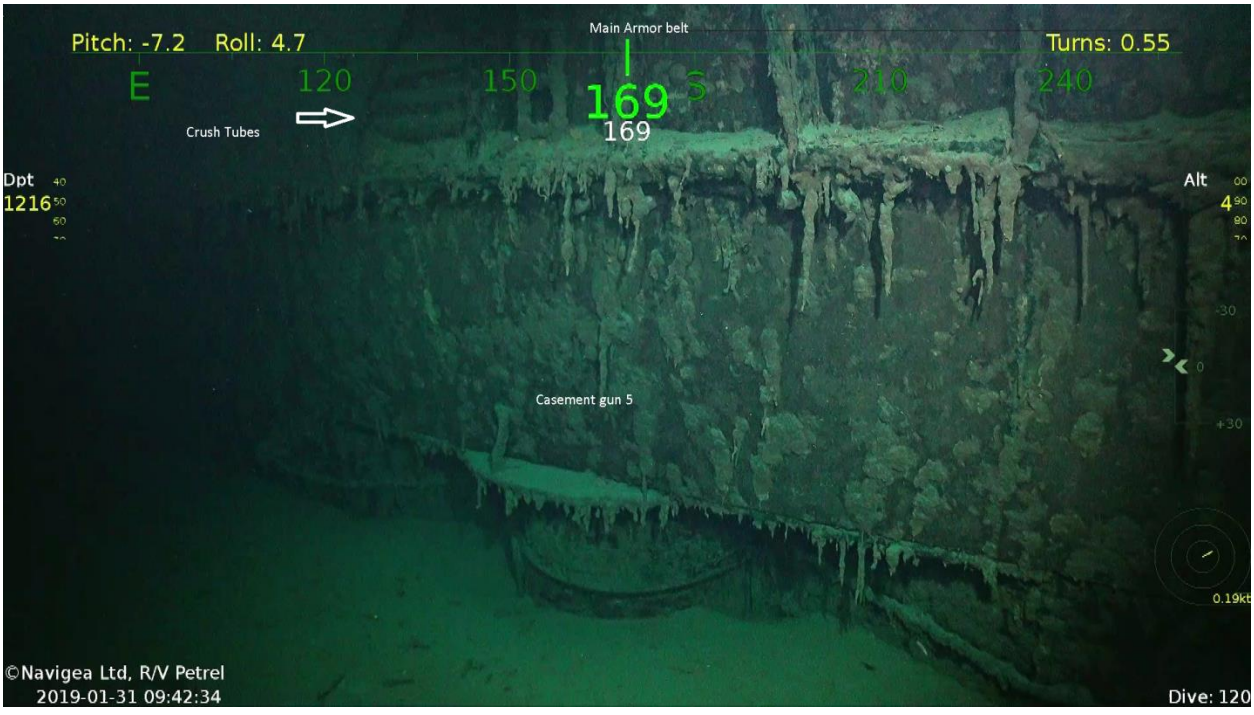

Figure 27 - Casement gun S5 showing blast damage to area outboard of main armor belt

Casement guns S5 and S7 are visible in Figure 27 and above them the torpedo defense system has been blasted apart exposing her main belt. The crush tubes are clearly visible, and the damage extends all the way down to her bilge keel. The barrel of casement gun S7 is

broken as can be seen in Figure 28; this occurred when *Kirishima* landed on the sea floor. There is no apparent hole in the main belt. The lower 3-inch belt has been pushed inboard, but this may be due to implosion of the inboard tanks that supported it and not directly due to battle damage. I have two possible explanations. The first is the least likely. There is no documentation on how effective the crush tubes would be at removing the AP caps from major caliber projectiles. They only covered the small area that remained above the waterline. While in theory it is possible a U.S. projectile could be de-capped by the crush tubes and then suffers nose shatter on the main belt which results in a pre-mature detonation of the projectile. I did not see any impact scar on the main belt. There is still a lot of support structure intact and if the main belt had suffered such an impact, I believe I would see this structure swept away.

Figure 28 – Casemate gun S7 with broken barrel

Figure 29 - Area above casement gun S7 showing extent of blast damage

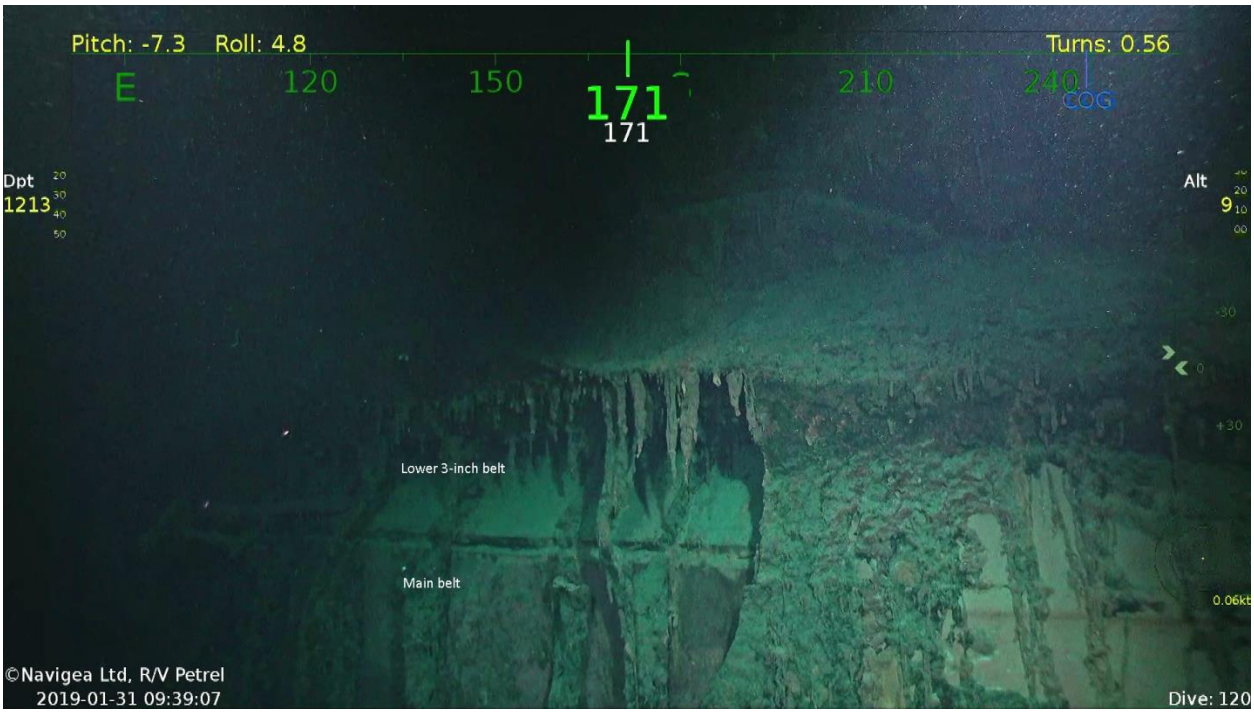

Figure 30 - Area above casement gun S7 and exposed main armor belt and lower 3-inch belt

A second possibility is the projectile impacted the water first which would begin fuze action and entered the torpedo bulge and detonated before it contacted the main belt and blasted a large section of the torpedo bulkhead and outer shell away. Though the damage looks impressive it is relatively minor in terms of reducing *Kirishima*'s combat capability. In this case her armor won. I believe this impact also occurred on *Washington*'s third salvo at 0101. Lt.(jg.) Kobayashi believed that *Kirishima* may have been hit by torpedoes and this damage may have given him that idea. From his perspective only a small area would have been visible looking over the side, but we know no torpedoes were fired at *Kirishima*. Lt. Cdr. Hank Seely saw from the *Washington*'s shells detonating at 0101 and I believe that this is one of those shells.

Figure 31 - Beginning of starboard hull break with hull shattered and peeled back from within

The ROV moves forward to the starboard hull break at about frame 94 in Figure 31. It is close to where casement gun 3 should be but I believe this gun is buried in the mud. I was hoping to find evidence for one more impact that Lt. Ikeda said was in this area. I believe the impact is buried in the mud and is not visible. In my 2009 article I estimated the projectile impacted the forward 5-inch gun mount that was in this approximate position. Unfortunately, all this area is buried and direct confirmation of a projectile hit in this area could not be confirmed.

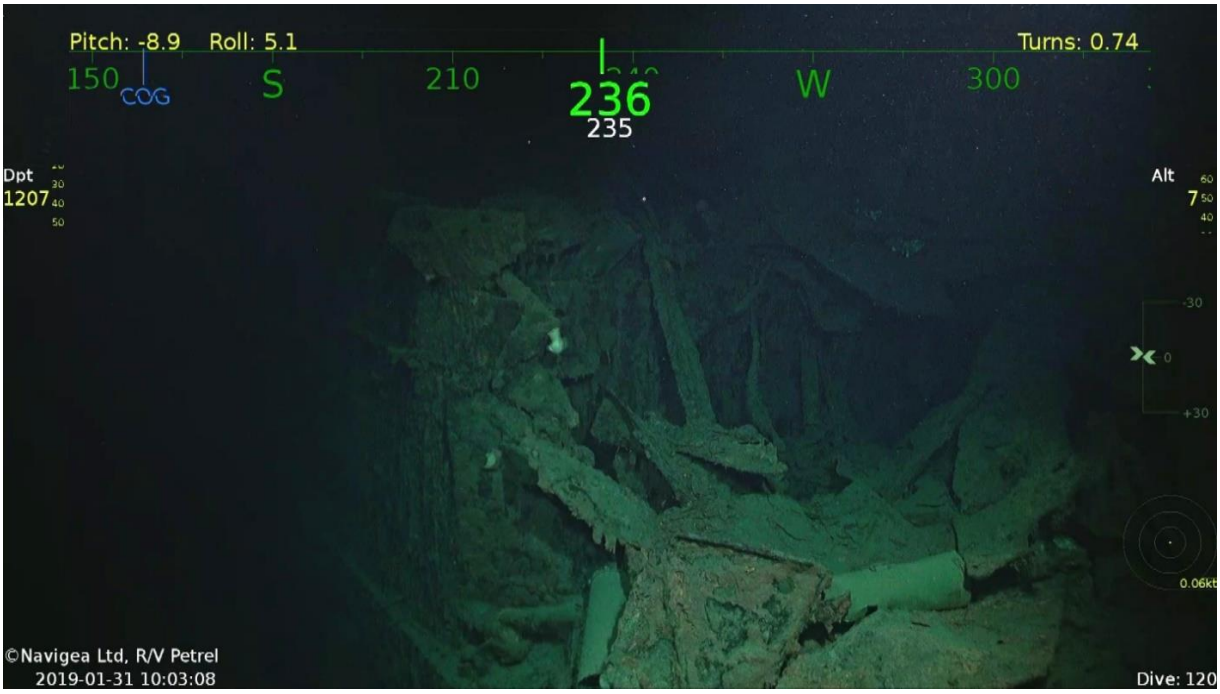

Figure 32 - Starboard hull break with secondary powder casings still on wreck

Figure 32 and Figure 33 show the massive internal damage at the starboard break with multiple powder casings still lying within the wreck. These tell us that we are at the secondary powder magazines. There are thousands more in the debris field along with main powder casings. When *Kirishima* capsized, she capsized to port. This would throw all the projectiles to the port side of the compartments that contained them. Then she sank stern first rising vertically as she plunged. This would pile up the projectiles on the aft walls of the compartment that contained them. It is actually difficult to get projectiles to detonate. Simply tossing them around typically does not provide sufficient force to initiate the fuze or crush the projectiles. They need a massive shock. Prior to her sinking all the forward powder magazines have been flooded and both barbettes have holes in them so the barbette structures are going

to flood immediately.

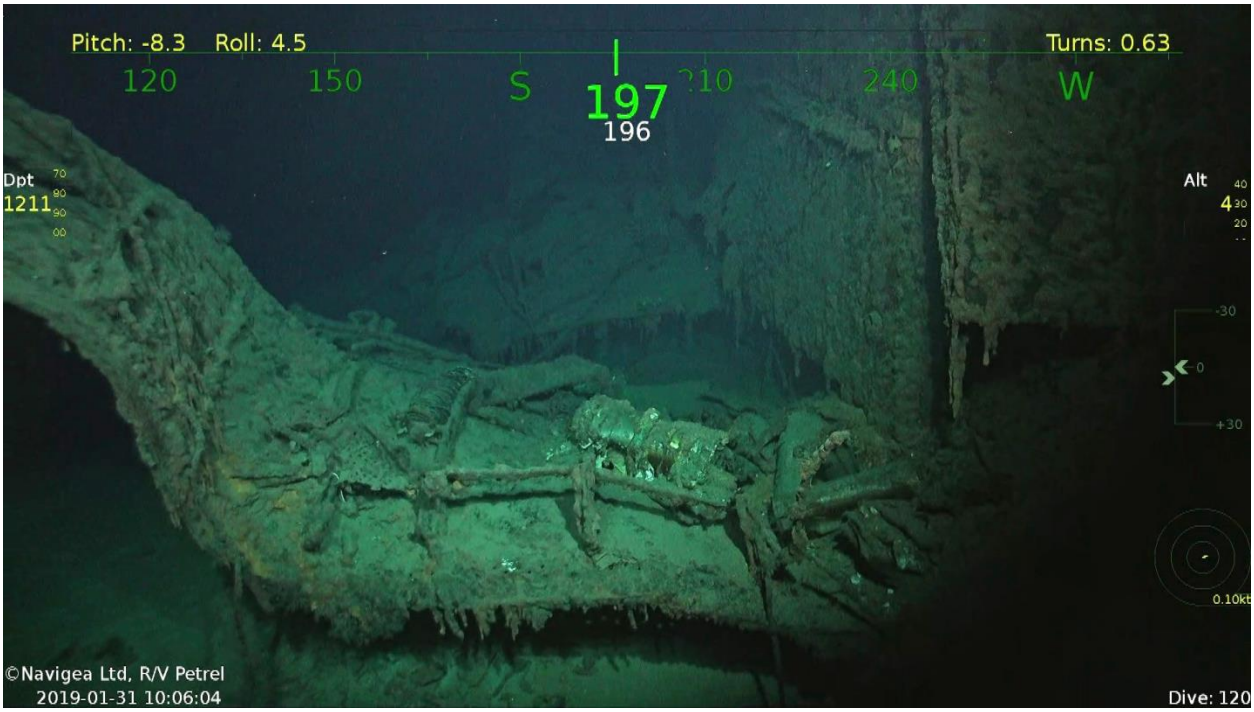

Figure 33 - Starboard hull break showing shattered hull

The problem I see is that if we look at the U.S.S. *Arizona* as an example then when her forward powder magazines detonated they did not destroy the heavily armored barbettes or turrets. The *Arizona*'s detonation was not capable of blowing out her side though her port side was heavily bulged outward.[1] It did collaspe all her decks but the explosion then vented through her hull forward of the armored belt. This implies to me that *Kirishima* suffered an even greater explosion, yet her powder has not been consumed, so what was the source that could produce an even greater explosion then her powder? For an analysis of this interesting subject, please see Appendix 1.

[1] The fact that *Kirishima*'s heavily armored barbettes for both turrets 'A' and 'B' have been shattered is a clue that the center of the detonation originated within the barbette structure.

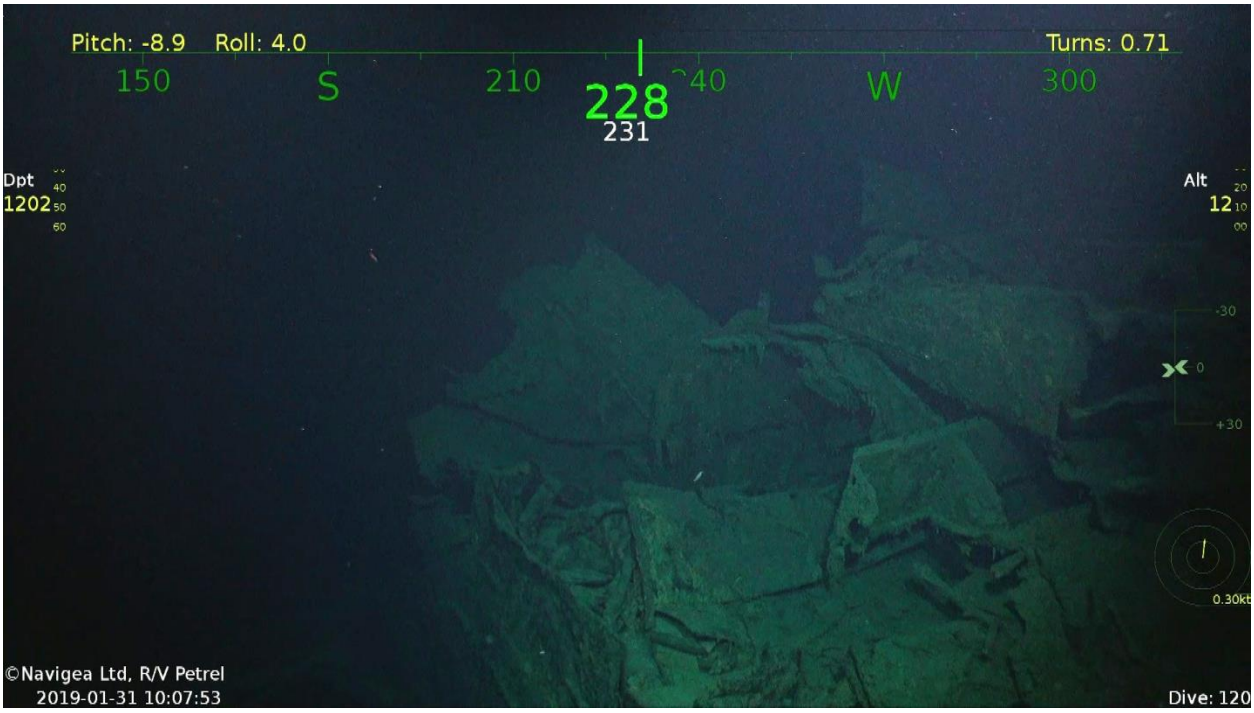

Figure 34 – *Kirishima*'s hull has been peeled back from within

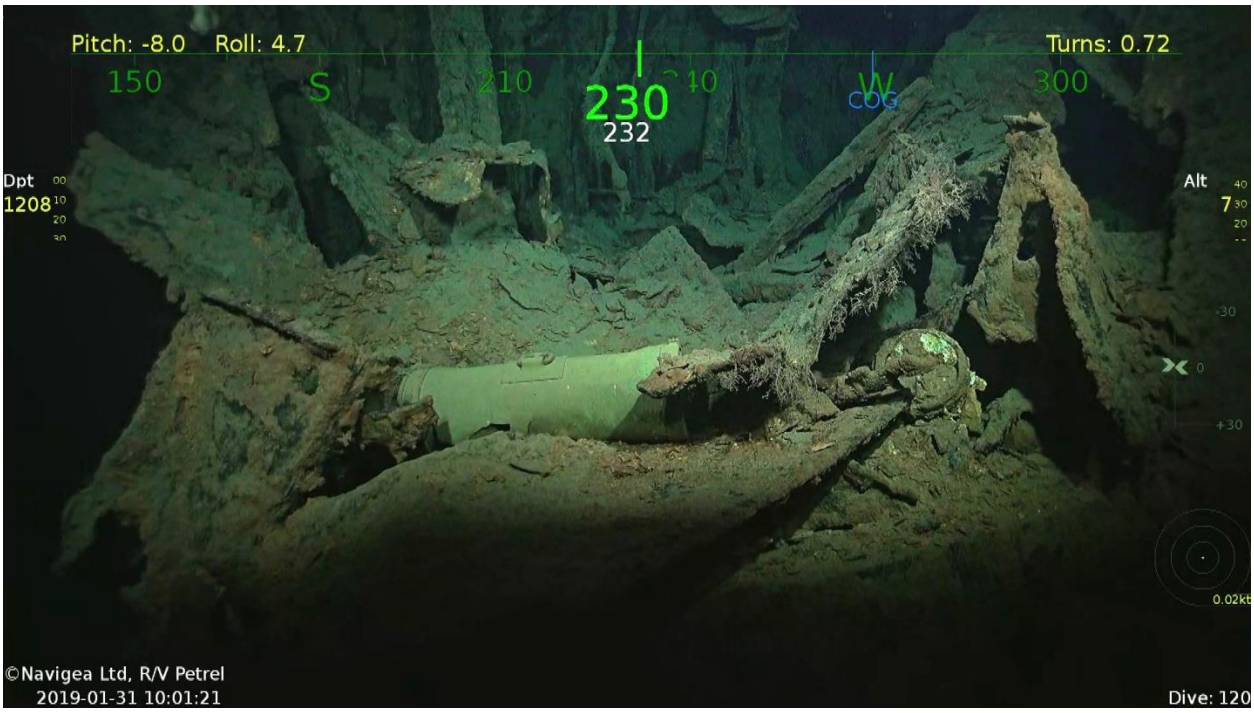

Figure 35 - Secondary powder casing

Her overall condition is an indication that another explosive was needed. That explosive was hydrogen gas. You need heat and the magnesium was the only thing that can provide the

heat that turns water into an explosive element by seperating hydrogen from oxygen. Simply put if no magnesium fire was present she lands on the bottom intact. This largely supports the hits to the forward barbettes despite their destruction. If these hits did not take place then *Kirishima* lands on the bottom intact. I believe something similar occurred on the *Musashi* and why she suffered a detonation that completely obliterated her after she left the surface. When the explosion breaks forward of barbette 'A' it reaches her chain locker, and this was where her hull breaks and some of the anchor chain spills out and will fall over her stern. The debris falls to the south but the wreck herself lands with the severed bow pointing more to the east.

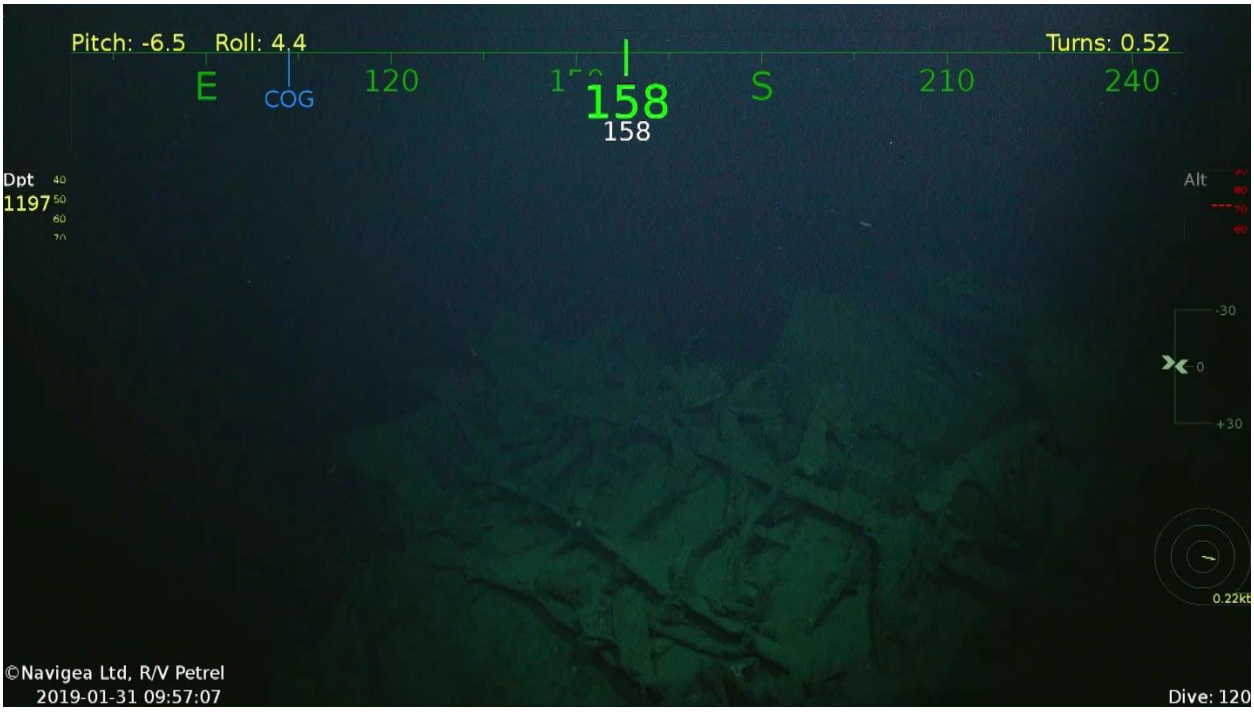

Figure 36 - Keel plates folded back over *Kirishima*'s keel

Her bottom plates of her keel now peeled back over her keel from a massive internal force that ripped her apart. This is where the 2019 expedition ended.

Below in Figure 37 is my "Hit Location" drawing from my 2009 article which has been updated to reflect the new information discussed in this article. Green is starboard side, red is port side, blue is unconfirmed. I believe that it is safe to say that *Kirishima* was struck between 17 and 21 times by 16-inch projectiles and between 17 and 20 times by 5-inch projectiles. We do not know for certain the caliber of projectile that struck the main gun range finder or that of the two projectiles that struck the bow, which are currently listed as part of the 5-inch total.

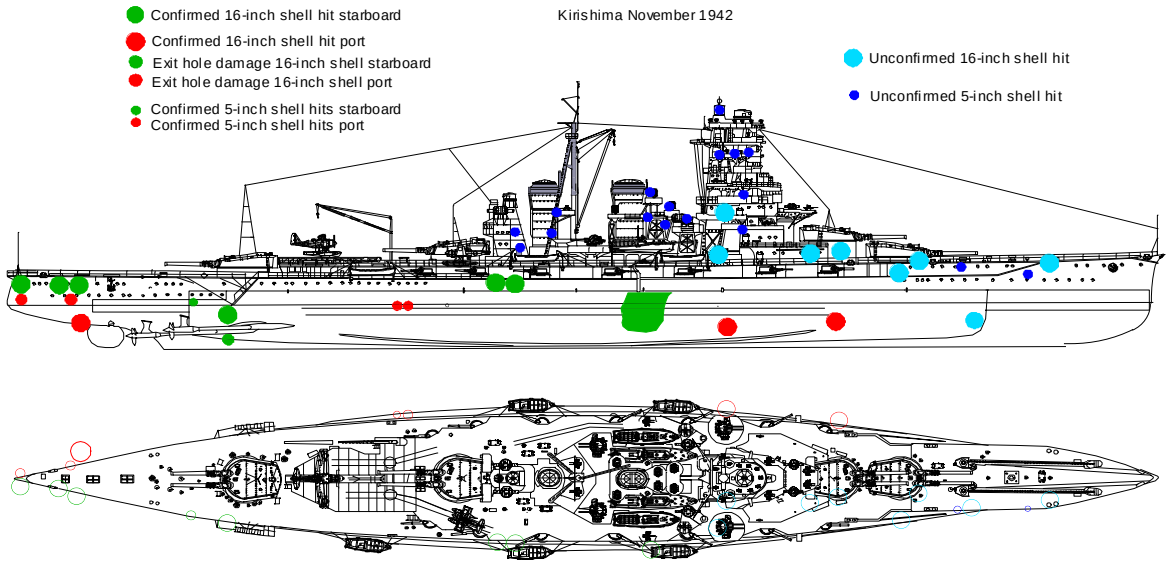

Figure 37 - Updated *Kirishima* hit locations based on 2019 expedition

In conclusion, I would like to thank Robert Kraft, Paul Mayer, Anthony Tully and Paul G. Allen's Vulcan Inc. for including me in this fascinating project and allowing me to take part in a small way. I never expected anyone to return to *Kirishima,* but the new film of her condition surpassed my wildest dreams.

Appendix 1 – Destruction of the Forward Barbettes

- The *Kirishima* at her final battle was loaded with more Type 3 ammunition then she normally carried. Normal outfit was 20-30 shells per gun. The *Kirishima* may have actually had as many as 50 Type 3 shells per gun for her planned bombardment.
- The *Kirishima* fired more Type 3 than any other kind of projectile with 68 of these being expended during the battle. 22 Type 0 HC rounds and 27 Type 1 AP rounds were also expended.
- The *Kirishima* lost both forward turrets in combat with Turret 'A' being lost early in the battle. She was still firing Type 3 ammunition when Turret 'A' was lost and more than likely also when Turret 'B' was lost.
- For the 14"/45 Incendiary Type 3 projectile, the ingredients for the incendiary tubes are found in U.S. Naval Technical Mission to Japan 0-19, "Japanese Projectiles – General Types" and are as follows: Polisulphide Synthetic Rubber 9.3%, Natural Rubber 5%, Stearic Acid 0.2%, Sulphur 0.5%, Ba(No3)2 40% and Electron Metal 45% (Electron Metal is a thermite mixture consisting of Magnesium 90%, Aluminum 3%, Copper 3%, Zinc 1-2% and Silicon 2%). The weight of these tubes is not given in O-19, so some extrapolation is required to get an estimate. From the shell and tube diagrams in O-19, a tube size of 25 mm x 90 mm with a 4 mm wall thickness was estimated. Using a material weight calculator program utilizing this tube size and the material percentages given above as inputs, a weight of 0.0927 lbs. (42 gms) per tube was calculated. Each shell held 480 incendiary tubes. Thus the total amount of incendiary material in each shell was calculated as x 0.0927 lbs. (42 gms) = 44.496 lbs. (20 kg). Besides for the incendiary material in the tubes, each shell also had a fuze and a length of "quickmatch" that ran the length of the shell. These last two items probably did not add much additional weight but would have speeded the burning process. Each barbette held 100 Type 3 shells (50 shells per gun) for bombardment missions. This means that the amount of incendiary material inside the shells in each barbette was 4,449.6 lbs. (2,018 kg). Of this, the magnesium contained in each shell was 480 x 0.0927 x 0.45 x 0.90 = 18.02 lbs. (8.2 kg) for a total of 1,802 lbs. (817 kg) for all 100 shells in each barbette.
- Within Turret 'A' barbette, assuming the Japanese had pre-positioned ten Type 3 projectiles per gun in advance of the battle, the barbette structure would hold twenty projectiles prior to the battle. Turret 'A' fired three times during the battle, expending six shells and thus leaving at minimum fourteen projectiles within the barbette and hoists when it was destroyed. Using the figures above,

each projectile contained over 44 lbs. (20 kg) of incendiary material in which 18 lbs. (8.2 kg) was magnesium. With an estimated fourteen projectiles within barbette one this single compartment had 252.3 lbs. (114.4 kg) of magnesium powder available to burn within barbette one. This is my low bar conservative figure for determining the minimum values of available thermite.

- At 0107 on the port side *Kirishima* took a below waterline hit in line with her Turret 'B' powder magazine. She did not explode. The most likely reason is the magazine had already been flooded prior to the hit.
- Lt. Ikeda documented all powder magazines both forward and aft were flooded after the battle.
- Lt Ikeda documented each forward turret suffered two direct hits to the barbette and that both forward turrets were smashed. At the ranges for the battle *Washington*'s 16-inch shells would have no problem penetrating the 9-inch armor.
- 16-inch shells detonating inside the barbette structure reproduces in many ways the *Iowa* accident within each barbette. In the *Iowa* all the powder charges within the barbette were eventually ignited and exploded. In the *Iowa* the crew sprayed water in an attempt to douse the inferno within the barbette. The projectiles being loaded were inert practice rounds and had no explosive filler.
- *Kirishima* was loading Type 3 incendiary rounds that are very thin walled, have a wood nose, use picric acid as a explosive filler, and have several hundred magnesium thermite incendiary tubes. The shell would be loaded on the hoist directly below four powder bags. The 16-inch American shell detonating within the barbette would easily set off the exposed powder bags. The thin walled Type 3 projectiles are vulnerable to battleship-caliber fragments striking their side which would easily penetrate the projectile and shock waves from the detonating powder would be able to detonate the picric acid main charge inside the projectile. Any Type 3 shells that are ignited would burn at 3,000 degrees centigrade and were capable of producing a flame 17 feet (5 m) long. At these tempertures the flames can melt right through the casing of any adjacent projectiles.
- This was a very different fire from what happened in the *Iowa*. The crew of *Kirishima* has nothing on board that can put out a magnesium fire. If they spray water onto this fire it would be so hot that it would immediately vaporize the water, separating hydrogen from oxygen and producing hydrogen gas which will ignite. So spraying water will increase the fire, not suppress it. CO_2 would also be ineffective at putting out a magnesium fire. What is unusual, however, is that magnesium is reactive enough to be combusted and oxidized in a reaction with

carbon dioxide: 2 Mg + CO_2 -> 2 MgO + C Under normal combustion/oxidation circumstances, oxygen is the reactant. Carbon dioxide fire extinguishers work by smothering a fire in carbon dioxide. This is only an effective means of extinguishing a fire if carbon dioxide itself cannot be used as a fuel source.

- With no ability to put out the fire within the barbettes, turrets 'A' and 'B' will have to burn out on their own. They are completely ruined and even if she made it back to port they would be a total loss and have to be replaced. However, in the time it takes for her to sink the fires diminish but are still smoldering when she capsizes. This is based on documentation that the fires did diminish prior to her sinking. I do believe it is certainly reasonable to believe within the barbettes the fire was still smoldering.
- The *Kirishima* capsizes and then plunges by the stern. I no longer believe the turrets fell out as I now believe that they have retaining clips. I think my 2009 article was in error in this regard.
- As *Kirishima* sinks the water would attempt to flood the forward barbettes through the holes made by the 16-inch shells that destroyed them. However, the internal environment of this space is so hot any water molecules immediately vaporize. What most people do not realize is that the combustion of hydrogen and oxygen to form water is actually a reversible reaction depending upon temperature.[2] Water molecules that enter this environment immediately separate so that hydrogen gas and oxygen gas form into separate vapor clouds within the barbette and gun house structures. The initial temperture was actually too hot to ignite the hydrogen gas which needs the oxygen to burn.
- The sea water itself would not have had to have direct contact with the thermite itself as the reaction would have occurred even if the water was just in contact with metal that itself was being heated by the thermite. So as long as the

[2] Basically, the overall energy of a reaction is defined by the term Delta G, or the change in Gibbs Free Energy. It ends up the value of Delta G equals Delta H (the change in enthalpy or heat content) minus Delta S (the change in entropy or disorder) multiplied by the temperature (in an absolute temperature scale). Two other laws of thermodynamics come into play here also. First, for a reaction to occur spontaneously, the value for Delta G must be a negative number. Second, when a reaction is reversed, the magnitude of Delta G, Delta, Delta S do not change but rather the signs. It ends up that the value for Delta H for hydrogen and oxygen combining to form water vapor is a fairly large number (-285 kJ / mole) which is what makes hydrogen/oxygen gas mixtures so explosive at typical room temperature. However, the Delta S value for this reaction is only -0.189 kj/mole so that at 25 degrees C (or 298 degrees K), the overall Delta G value for this reaction would be such that the combustion is spontaneous. However, once the temperature gets above 1,300 degrees C, the sign for Delta G reverses meaning that the decomposition of water to hydrogen gas and oxygen becomes the spontaneous reaction and the combustion is no longer energetically favored. If the temperature stays above this temperature, the water will continue to decompose, and the hydrogen will not burn. The two gasses cannot recombine, and explode, until the temperature drops back down below this critical temperature AND there is some type of ignition event. – Thomas H. Pritchett Department of Chemical & Physical Sciences, Cedar Crest College.

internal temperature within the barbette remains above 1,300 degrees centigrade water molecules will be seperated into hydrogen gas and oxygen gas.

- This is important step in a vapor cloud explosion. Ignition of the flammable vapor cloud must be delayed until a cloud of sufficient size has formed. If ignition occurs as the flammable material is escaping, a large fire, jet flame, or fireball might occur, but a vapor cloud explosion is unlikely. The probability of explosion rather than fire increases with the size of the cloud, since the quantity of the mixture within the flammable range increases. So initially as *Kirishima* sinks the thermite fire in barbettes 'A' and 'B' have produced conditions that allow water to separate into hydrogen gas and oxygen gas but not ignite and this allows for the build up of these gases within the contained structures. Once the hydrogen starts to be generated by the water hitting the hot metal, it will continue to be generated as along as water is being exposed to temperatures above 1,300 degrees C.
- As *Kirishima* rapidly decends into the abyss the ocean is also rapidly cooling her off and temperatures within the barbette structures begin to fall. Once the collected gas mixture has cooled, it can be ignited by either the residual heat of the metal within the barbette or still burning thermite, or an electrical short. The critical minimum volume of the vapor cloud would be reached when the overall hydrogen gas concentration exceeded 4% by volume and the overall gas temperatures had dropped below approximately 1,100 degrees C.
- Deflagration to detonation physics can produce some of the largest explosions in the universe. The released material must be flammable and at suitable conditions to form a vapor cloud and in this case we have hydrogen gas which is an explosive gas.
- An ignition source is needed to initiate the explosion. Higher energy ignition sources can lead to a more severe explosion than do lower energy sources. Clearly the wreck shows she suffered an ignition source as her wreck has been blown to bits. I feel that any white hot metal debris once the vapor cloud cooled will set it off. In addition thermite still may be burning as well as her electrical systems shorting out as she sinks.
- Turbulence is required for the flame front to accelerate to the speeds required for a vapor cloud explosion otherwise, a flash fire will result. All the equipment in the barbette provides turbulence.
- Confinement of the cloud by obstacles can result in rapid increases in pressure during combustion. With the gun houses still in the barbette this fire is confined with the only venting is through the two holes made by the 16-inch shells that started the fire in the first place.

- Now the flame speed of the ignited hydrogen gas accelerates to the speed of sound which is 740 mph. At this point the confining presure of the hull structure can no longer accelerate the flames so an over-pressure develops within the fire. Because of this over-pressure and the turbulance caused by the internal stuctures the flame spits out a particle at super-sonic speed and as soon as that occurs you get detonation just like high explosives with the formation of a shock wave.[3] Four big explosions rip through her obliterating both forward barbettes and detonating her forward main and secondary shell magazines due to the shock wave. Her bow structure being largely vertical was destroyed but the stern section simply sinks. With no fire aft, the aft magazines remain stable. I believe in the 1992 film I saw debris that looked burned and metal turned white. It is also possible within the debris we may find junk welded to each other that are not supposed to be welded together. Every shell was consumed forward and the powder was crushed, flattened, ripped open and tossed around but was not consumed because it can't burn underwater. This was exactly what was found in the debris field which was documented by Charles Haberlein in 1992. Her hull was peeled back from within telling us she blew up from an inside force. Her barbettes were obliterated and that required a massive force. The forward gun houses are obliterated.
- The massive hydrogen vapor cloud once it breaks free from the confined space of the barbette and hull rapidly cools off and the hydrogen gas recombines with oxygen gas to make water.

[3] Shortly after ignition, once the turbulent flame becomes fully developed, pressure begins to rise throughout the volume of the flame accelerating it and forming the leading planar global shock. Shock waves, repeatedly generated within the flame, coalesce at the leading shock front amplifying it until the detonation is ignited. The underlying physical cause of the spontaneous pressure increase is the development of the supersonic flow of burning products downstream of the flame. In the reference frame co-moving with the flame, fuel enters the flame with the speed equal to the flame burning velocity. Products leave the flame with a much higher velocity due to the overall fluid expansion caused by heating. This means that at a certain subsonic flame speed, the product velocity will become equal to the speed of sound. At this point, any pressure increase as a result of burning cannot be propagated upstream by pressure waves, which will cause an overpressure to form within the flame volume. Such overpressure compresses and heats up the fuel, which, in turn, accelerates burning and further increases the outflow velocity of the burning products. This promotes pressure confinement and sets off the runaway process, which ultimately leads to a detonation. The critical threshold, at which this process begins, is known as the Chapman-Jouguet (CJ) deflagration speed, the theoretical maximum speed for the steady flame propagation. Laminar flames, both chemical and thermonuclear, never reach such high speeds. Turbulent flames, in contrast, can become sufficiently fast. A.Y. Poludnenko, T.A. Gardiner, E.S. Oran, Phys. Rev. Lett.107 (2011).

Appendix 2 - Wish list for possible future expeditions

The primary goal of mine has always been to see if the wreck could confirm Lt. Cdr. Tsurukichi Ikeda's account of her battle damage. To this end I gave Anthony Tully the following list of areas I hoped this new expedition would confirm.

- A sonar image and map of the entire wreck and its debris field.
- Actual measurements of the wreck.
- A complete film of both the port and starboard sides of the hull section.
- Film documentation of the debris field and documentation of what lies within it.

The 2019 expedition largely succeeded with the first three but did not have the time to film the debris field. Should there be a future expedition to photograph the wreck, some unexplored areas that would be of interest to explore would be the following.

- Documentation of the thousands of main and secondary powder casings still on the sea floor and the absence of any projectiles.
- Documentation within the debris field of any debris that was burned white, melted, or parts welded together in a manner that make no sense. These would be physical evidence of a magnesium fire.
- Photographing any remnant of a bow section beginning around frame 40 to frame 1. This would help determine if as many as four reported hits took place.
- Can the main gun rangefinder be located, and an additional hit confirmed?
- Can the forward turrets and guns, or what remains of them, be located in the debris field?
- Locate what remains of the armored barbettes for both forward turrets which have been shattered but may show signs of being exposed to extreme heat and further evidence of a magnesium fire within them.
- Concerning her sister *Hiei*: Look for her bow section, which I suspect is intact, and determine if possible if the forward turrets are still in their barbettes. It is possible that as *Hiei* was also carrying additional Type 3 projectiles that her bow section suffered a similar explosion and was obliterated, making it more difficult to locate. Until the bow section is identified as either an intact section or as a massive debris fields, her story will remain incomplete.

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Other Information

I would like to thank Thomas H. Pritchett, MS, Department of Chemical & Physical Sciences, Cedar Crest College, for his help in explaining and determining the mechanisms of underwater explosions.