

"MEDITERRANEAN ON THE ROCKS"  
SHOW 1004

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EPISODE OPEN

ALAN ALDA: Why does a Mediterranean fishing net come up filled with Caribbean weed? On this edition of Scientific American Frontiers, ancient and modern mysteries of the Mediterranean.

ALAN ALDA: (Narration) We're on the trail of an underwater green invader...

ALEX MEINESZ: It's a kind of toxic.

ALAN ALDA: (Narration) We're working out how to build a Stone Age boat...

BOAT CREW: Hey-oh-hup.

ALAN ALDA: (Narration) We're trying to produce copper in a three thousand-year-old smelter... And we're tracking down new ideas about the Sea's unique wildlife.

ALAN ALDA: I'm Alan Alda. Join me now for Mediterranean on the Rocks.

ALAN ALDA: (Narration) Hold on. We're heading into the Mediterranean, through the Strait of Gibraltar. Here comes the water. The Mediterranean last filled up only 5 million years ago... until it looked like this. Let's explore.

ALAN ALDA: We're beginning our Mediterranean journey in Nice on the French Riviera. It's perhaps the most famous of the resort areas in a part of the world that is apparently nothing but resorts, stretching from the Spanish beaches in the west for 2,000 miles across to the Greek Islands in the east. This is going to be a program not just about vacation land but about the reality of the Mediterranean today -- and it's a mixed picture at best. Today hundreds of millions of people living around the Mediterranean use the sea for just about everything -- as a vital

source of food, as a major highway and of course as a huge waste dump. And everywhere there are signs of stress, as we'll see in stories about turtles, tuna and whales. That's right, whales! The Mediterranean has lots of whales. Of course it's not just the heritage of the wild life in this sea that we have to worry about, it's our own human heritage too. Ten thousand years ago, people first settled down as farmers on the shores of the Mediterranean. And at about that same time, people first ventured offshore on the waters of the Mediterranean. Later in this program we'll be meeting archaeologists working hard to secure that human heritage. But first, an underwater horror story -- the invasion of the green seaweed. Stay tuned.

## THE GREEN INVADER

ALAN ALDA: How long have you been studying this caulerpa?

ALEX MEINESZ: More than 10 years.

ALAN ALDA: 10 years.

ALEX MEINESZ: Yes, 10 years

ALAN ALDA: (Narration) We're in a small town just along the coast from Nice. Alex Meinesz, a biology professor from Nice University, is taking me out fishing.

ALAN ALDA: Do you think in those ten years, how much has it increased?

ALAN ALDA: (Narration) As with thousands of places like it around the Mediterranean Sea, this town depends on a mix of fishing and tourism for its livelihood.

ALAN ALDA: Is this the fishing boat we're going on?

ALEX MEINESZ: Yes. On peut monter?

ALAN ALDA: Okay, thanks. Bonjour!

FISHERMAN: Bonjour! Patrick.

ALAN ALDA: Patrick, Alan.

ALEX MEINESZ: Alex. Bonjour!

ALAN ALDA: (Narration) We're on the Vergé family boat. The waters around here have been fished for generations. Until now, that is. They don't fish here any more. We had to persuade them to set their net out last night, just so we could film the result. And the result is this.

ALEX MEINESZ: Caulerpa

ALAN ALDA: Yeah.

ALEX MEINESZ: Caulerpa

ALEX MEINESZ: Look. Oui, oui. On arrêt un peu, uh? Look. And this caulerpa clogs the nets and the fish see the nets and there is no fishes.

ALAN ALDA: Oh, I see. So it hurts fishing just because...

ALEX MEINESZ: They see the nets.

ALAN ALDA: ...it calls attention to the nets.

ALEX MEINESZ: Yes.

ALAN ALDA: (Narration) The weed, called *caulerpa taxifolia*, doesn't belong here. It's a tropical plant, common in the Caribbean and other warm waters. The northern Mediterranean gets cold in winter, but somehow the caulerpa is surviving, and thriving - nothing can touch it.

ALEX MEINESZ: When you broke it, there comes a kind of juice out of it, you see?

ALAN ALDA: Does that juice have anything in it that keeps away predators?

ALEX MEINESZ: Yes, absolutely. That are terpanes, caulerpanines. And this is a kind of toxic matter and a repellent matter. So the fish don't eat it.

ALAN ALDA: So it repels fish. So in this area nothing is a natural predator.

ALEX MEINESZ: No! You see all the leaves are entire. Nothing...

ALAN ALDA: Nothing has been eating it!

ALEX MEINESZ: No, no biting crease.

ALAN ALDA: Yeah.

ALEX MEINESZ: On y va?

ALAN ALDA: On y va. Holy moly! He really jumps in!

ALAN ALDA: (Narration) Alex took us into the shallow water near the town's bathing beach. Everything below was covered by the caulerpa - rocks, sand, mud. There's nothing else down here, no other plants, barely a fish. It's a classic example of an alien plant that just takes over - like kudzu. Nothing eats it, and nothing competes with it.

ALEX MEINESZ: It's full, uh?

ALAN ALDA: Yeah, there's a lot of it down there.

ALEX MEINESZ: All the bottom is covered, eh?

ALAN ALDA: There's a lot there!

ALEX MEINESZ: All the bottom is covered.

ALAN ALDA: (Narration) The caulerpa arrived here about nine years ago. Advancing at an inch a day, it has ruined the fishing and it'll soon clog the town beach. It's the same disastrous story, spread out along 1,000 miles of Mediterranean coast. Caulerpa is easily spread. It's carried along in fishing nets, and there are millions of small boats in the Mediterranean - all with anchors.

ALEX MEINESZ: A little piece like this, I put this in the water, after 6 months you have 3 square meters, with this little piece.

ALAN ALDA: Any part of this?

ALEX MEINESZ: Any part. Any part.

ALAN ALDA: (Narration) With its rapid spread from fragments, and its cold water survival, caulerpa in the Mediterranean is behaving in ways that shocked marine plant experts like Alex. After years of investigation, Alex is pretty certain he knows how this disaster happened. This is the aquarium at the famous Monaco Oceanographic Museum, where Jacques Cousteau was once director. In the early 1980s the Museum, along with several other European aquaria, started using a decorative, and easy to grow, plant in their tropical tanks. The plant was caulerpa taxifolia. It's still used here today, as it is around the world. Alex believes that somehow some fragments of caulerpa were released from the tanks into the sea. A museum diver first saw caulerpa right outside the building, on the

bottom, in 1984. It covered just one square yard. By 1989, when Alex first saw it, it covered 2 acres. By 1990 it was at nearby Cap Martin, next year Toulon, 100 miles away, and now it's found from Spain to Croatia. With no natural enemies to hold it back, the caulerpa has been steadily smothering normal Mediterranean sea life. In the shallow areas, a complex community of over a thousand different algae, shellfish, worms and fishes has evolved around meadows of native sea grass. In the darker depths there's a different balance, with the grass giving way to red sea fans. This is the steep, 100 foot rock wall off Cap Martin, once a favorite spot for scuba divers. The film is from 1996, shot as the caulerpa was taking hold. Alex has been diving here every year since the caulerpa arrived. As the alien plant advances, it blocks light out -- from the red sea fans, for example, which die off. Alex has seen the same process repeated all over the rock wall. Did this all originate with the Monaco aquarium? Genetic analysis has shown the caulerpa is a mutant strain, unique to European aquariums including Monaco, and not found in the wild. But we'll never know for sure how it first got loose. In the summer of 1999, our underwater cameraman swam down the rock wall at Cap Martin to record the progress of the caulerpa. The wall is now completely covered. The last sea fans are dying. The wall is essentially a biological desert. Once again we're looking at caulerpa growing in an aquarium. But there's something else - it's a kind of slug, and it's eating the weed. The result - all over the tank, ghostly white fronds of weed, with their toxic juice sucked right out by the slugs. The slugs are being studied in his lab at the University of Nice by

ALEX MEINESZ: In his view, they represent the single best hope for controlling caulerpa taxofolia in the Mediterranean. We've jumped 2,000 miles across the Atlantic to the Indian River in Florida. Alex's slugs came from here, collected by Cecelia Miles, a marine biologist from Florida State University. Here caulerpa is eaten -- and controlled -- by the highly specialized slugs, as it is further south all over the Caribbean. The hope is that slugs from Florida -- the northern extreme of their range - might be hardy enough to survive the Mediterranean winter. In the summer of '99, Cecilia collected and packed a batch of Florida slugs for shipment to Alex in Nice. The slugs had their own air supply for the flight, and were escorted across the Atlantic by a French grad student.

GRADUATE STUDENT: And I see you when I get back. See you Cecilia. Bye bye.

ALAN ALDA: Here you were a student of caulerpa and all of a sudden it shows up on your doorstep...

ALAN ALDA: (Narration) Alex has been studying different slugs for years. The Florida batch had been in residence at Nice University for about 2 weeks when I visited. His work with slugs and caulerpa is done on a shoestring budget, in a makeshift lab behind the biology building. The Monaco Aquarium connection

makes this a very political subject, so research grants have been hard to come by.

ALAN ALDA: ...so you've got a chance to see who's working out.

ALEX MEINESZ: Yes. Come in, please. Come in.

ALAN ALDA: So they're in there, I don't see any slugs.

ALEX MEINESZ: Yes, here.

ALAN ALDA: Oh yeah. yeah, yeah! Now is he eating now?

ALEX MEINESZ: Yes, I think so, yes.

ALAN ALDA: So these slugs really like that toxic stuff.

ALEX MEINESZ: Yes. They need the toxic, because they take the toxins and they stock it in them and then the fishes doesn't eat it.

ALAN ALDA: Oh, I see. So the slugs use the toxins to keep the fish away from them!

ALEX MEINESZ: Exactly. Exactly. Exactly.

ALAN ALDA: (Narration) The slugs have other highly specific adaptations to caulerpa - they need caulerpa cells as part of their own metabolism, and they have a special tooth which matches only caulerpa cell structure. Alex argues that the slugs are so exquisitely adapted to their one food that releasing them into the Mediterranean to control the invasion biologically would present a very low risk. I asked him about it.

ALAN ALDA: How do we know the slugs that you bring in won't adapt and find some other way to live in addition to caulerpa?

ALEX MEINESZ: When the slug have no more caulerpa, they can not, in one generation say, Ah, we shall change our tooth, our mouth, our toxin, to eat other things. You understand? You understand?

ALAN ALDA: That takes a lot of plastic surgery!

ALEX MEINESZ: You understand?

ALAN ALDA: Sure, sure!

ALEX MEINESZ: When there is caulerpa, they eats caulerpa. No problem, no problem. When they see there is no more caulerpa, it is too late. It's too late.

ALAN ALDA: (Narration) Alex's slugs may be the only way to go. All kinds of non-biological control methods have been tried - like releasing poisonous copper from underwater electrodes... Or simply scraping the weed off... Vacuuming it up... Freezing it with dry ice... Scalding it with hot water... Or cutting off its sunlight. But there's nothing that's practical on a large scale, except the slugs. I asked Alex again, Is it really smart to release the slugs into such a paradise of food?

ALAN ALDA: All of a sudden, they're dining out every night. They're going to Maxim's every night. And they're doing pretty well. Now, you're liable to have some pretty fat, happy, healthy slugs around looking for trouble.

ALEX MEINESZ: No, no. You have a prairie of caulerpa with many slugs in it and then they control the caulerpa and it is finished, that we think. But what you want? Do you want to have a Mediterranean Sea full with caulerpa without any control method? We must have a predator for this invader. Without predator, the caulerpa -- that is a risk that we see now. We can see, you have see it when we snorkeled. You see with the fisherman. It covered all the bottom and it expands every year. So what do we do? Do we do nothing? Or do we try this?

ALAN ALDA: If you can't get rid of it, if the slugs don't work, if the slugs are too dangerous, if the slugs work but governments won't let you use the slugs, what will the caulerpa do? What will happen to the Mediterranean?

ALEX MEINESZ: What happens is exactly the same that happened since ten years. It extends. It extends every year, in new country, new regions. And we think that this algae is able to colonize most of the region of all the Mediterranean Sea.

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## TURTLE HOSPITAL

ALAN ALDA: (Narration) The Mediterranean is a vacation paradise. Waterfront real estate is at a premium. Almost every strip of sand is occupied. For those reasons, the Sea's turtles are having a tough time. All over the world turtles are being crowded off nesting beaches, hit by boats and caught in nets, but the process has gone furthest in the busy Mediterranean. Now there's a network of biologists dedicated to saving the animals that remain. Europe's oldest aquarium, here in Naples, is at the forefront.

ALAN ALDA: So this is the turtle hospital?

DR. BENTIVEGNA: Yes.

ALAN ALDA: Now what did this turtle have wrong with him?

DR. BENTIVEGNA: This turtle had problems eyes.

ALAN ALDA: Eyes! What was wrong with his eyes? Something contagious.

DR. BENTIVEGNA: Conjunctivitis.

ALAN ALDA: She has conjunctivitis?

DR. BENTIVEGNA: Yes, but very serious.

ALAN ALDA: What's this problem?

DR. BENTIVEGNA: The problem is ingested hook.

ALAN ALDA: He got a hook in his throat? And it stayed in his throat.

DR. BENTIVEGNA: Yes.

ALAN ALDA: (Narration) The hook was successfully removed two years earlier, at the Naples vet school. It may seem like an extraordinary effort to devote to a single animal, but every individual counts now. There are only 2400 nesting female turtles left in the entire Mediterranean, down from hundreds of thousands in the past.

DR. BENTIVEGNA: Now she's very, very good and I release now this Logger, next September.

ALAN ALDA: What about this one over here?

DR. BENTIVEGNA: The shell was broken by boat propeller.

ALAN ALDA: (Narration) This is an amazingly common accident in the busy Mediterranean. Nearly 2 years ago,

DR. BENTIVEGNA: repaired the loggerhead's shell with the same surgical cement used for people. Now it's time for a checkup across town at the vet school.

DR. BENTIVEGNA: [Italian]

ALAN ALDA: (Narration) By the way, our restless young patient is named Carapax.

ALAN ALDA: You name them. You take care of them. You feed them.

DR. BENTIVEGNA: Yes.

ALAN ALDA: Do you get emotionally attached to them?

DR. BENTIVEGNA: Yes, yes. I love. I love these animals.

ALAN ALDA: You love them, yeah. Do you usually X-ray turtles?

RADIOLOGIST: A few times. Not usually.

ALAN ALDA: (Narration) The trick to X-raying turtles is to grab the moment.

DR. BENTIVEGNA: [Italian]

RADIOLOGIST: So here we see an area of lower density fracture in the bone. The interesting part is here, we see higher density and that means that new bone is being formed and the fracture is being repaired.

DR. BENTIVEGNA: To see this that our turtle is good, in good condition, it's very important. I am happy.

ALAN ALDA: (Narration) It's Fall, and the team from the Naples Aquarium is taking 14 of their best patients for a boat ride. They're heading 100 miles south to the relatively isolated volcanic island of Stromboli. The Aquarium is now releasing about 25 rescued turtles a year. It's a small number, but significant. A young female may go on to breed for 50 years or more, laying her eggs on one of the nesting beaches now protected in 7 Mediterranean countries. With luck, hard work, and dedication, turtles can still have a future in the Mediterranean.

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## THE PAPER BOAT

In Athens 2500 hundred years ago, the classical Greeks were inventing Western art, architecture, democracy and so on. But we're heading out of town, into the Greek countryside, to a much earlier time. We're looking for a cave by the sea, once occupied not by classical Greeks, but by people from the Stone Age. It's

likely that these people invented one of the most basic human tools - boats. This is the cave, called Franchthi. We're here with a Boston University archeologist, Curtis Runnels, and Harry Tzalas, an expert on Greek maritime history.

CURTIS RUNNELS: So here's the first trench, Harry, that was excavated. So then you see this deep trench and what we did here was dig straight down through a whole series of Neolithic layers. See those dark layers of charcoal and the lighter gray or even whitish layers that are ash? There have been fires in that region continuously during the Neolithic period.

ALAN ALDA: (Narration) The Neolithic goes back about 7,000 years, and then deep layers of debris in the third trench showed occasional human occupation back another 20,000 years.

CURTIS RUNNELS: All that charcoal, the ash, the potsherds, the stone tools just slowly created a pile of earth here until this is, as you see, a mound, sloping away from us.

HARRY TZALAS: It's a time capsule.

ALAN ALDA: (Narration) Around 5,000 years ago a section of roof collapsed, the cave became an uncomfortable wind tunnel, and the people left. But they left behind a trail of clues that Curtis and Harry believe leads back to the world's first boats. The trail starts with stone tools uncovered in the cave. Curtis excavated thousands of tools and stone fragments from toolmaking. There are probably millions still buried. The tools are made of obsidian, a volcanic glass.

CURTIS RUNNELS: There we go. Perfect. Now when we turn that up you'll notice how the edge is continued around here and you can actually begin to see some shape here.

ALAN ALDA: (Narration) You can imagine toolmaking skills being taught just like this, in Franchthi cave.

CURTIS RUNNELS: Excellent. You just made a perfectly good hand axe, that would be, let's put it this way, you could have used this to introduce yourself to early hominid society. You can just do this...

ALAN ALDA: I could just hold that up...

CURTIS RUNNELS: Hold that up and say, oh yeah you know what you're doing.

ALAN ALDA: It's like my Visa card.

CURTIS RUNNELS: That's right, sure. It's your introduction to prehistoric society.

ALAN ALDA: Do you accept these?

CURTIS RUNNELS: I bet they would because if they didn't, right...

ALAN ALDA: (Narration) About 13,000 years ago, not just occasional but continuous human occupation started at Franchthi. A little later, the toolmaking improved. It was my turn to try making one of these more sophisticated tools.

CURTIS RUNNELS: Yes, excellent. Yes. There you go. I think you can stop there for a moment because look how nicely that's coming out.

ALAN ALDA: (Narration) Here's my rather crude effort... and here's the beautiful blade Curtis made in the cave. 30 years of toolmaking have given him an insight into the thinking of our stone age ancestors.

CURTIS RUNNELS: The edge had to be in their mind.

ALAN ALDA: There's a kind of strategic thinking going on.

CURTIS RUNNELS: Strategic thinking. Forward thinking -- that they knew what the final product was going to be and they had to go through these stages to do it. That shows human intelligence in its clearest form.

ALAN ALDA: It's like what Michelangelo said how...

CURTIS RUNNELS: Just take everything away except what looks like David.

ALAN ALDA: And they were beginning to do that.

CURTIS RUNNELS: Yes, yes. And they were doing that probably a million years ago. They were able to sculpt these rocks. They were not just breaking them in some random way. And this to me is the drive behind all of our technological productions even today.

ALAN ALDA: In what way?

CURTIS RUNNELS: It's first in the mind. It's first in the mind and then we project it on the raw material.

ALAN ALDA: (Narration) Now here's where the trail heads out to sea. All the tools found in Franchthi cave were made of obsidian from one place. That place is Milos, an island in the Cyclades chain, 100 miles from Franchthi. It's an open

water journey, even if you do hop around the islands. So what kind of Stone Age boats were used? Probably something like this. It's a reed boat on Lake Titicaca in the Andes. Or like this, on Lake Chad in central Africa. Or like this, on the Italian island of Sardinia. They're disappearing now - this film was shot in the 50s - but reed boats, once used all over the world, have a very long history. At least 6,000 years ago the Egyptians used papyrus reed boats on the Nile. They were perfect for gathering papyrus from the marshes, for hunting and for fishing. But these were small river boats, not suited to open sea. They may have looked something like this. It's a reproduction papyrus boat at Phaoronic Village, a living history exhibit in the middle of Cairo. Laid out along canals cruised by tourist boats are colorful scenes from daily life in ancient Egypt. The heart of the place is papyrus, the all purpose Egyptian raw material used for rope, sandals, mats and of course, paper. Hassan Ragab, who started Phaoronic Village, was dismayed that papyrus reeds were extinct in Egypt. So he re-introduced them, using plants from Sudan, 1,000 miles to the south. Here's our souvenir sheet of paper.

Recently there was some extra activity in the thick stands of papyrus now established nearby. We've asked Phaoronic Village to build us a reed boat, but unlike any they've ever built before. Our boat begins the way reed boats have always begun, with the first tight bundle. Just like the stone toolmaker, the ancient reed boatbuilder must have had in mind a final shape for his creation. Here's a vital step - swept up bundles for the ends, so the boat rides the waves. They're working to a design first created 11 years ago by Harry Tzalas, the Greek maritime expert, and based on the traditional Greek reed boat, the papyrella. He had to use the thin papyrus reeds - actually the last in Europe - available from the Greek island of Corfu. Harry, an experienced sailor, concluded the boat was too small to handle long open water journeys. For our Frontiers boat we're using the large reeds available in Egypt. The vessel's to be 20 feet long, containing half a ton of dried papyrus. It should be able to accommodate a crew of 8. As our boat took shape, Harry came down from Greece, making the last leg of his journey in a Phaoronic Village tour boat.

HARRY TZALAS: Hello.

ALAN ALDA: (Narration) When shown the boat by Abdelsalam, son of the Phaoronic Village founder, Harry was enthusiastic about the size of the reeds, and the virtues of papyrus - known no doubt to Stone Age people, as well.

HARRY TZALAS: You cannot sink a papyrus boat. It is impossible to sink it. You can destroy it but it will not sink. Inside you have millions of tiny minuscule air chambers and that's what gives the buoyancy.

ALAN ALDA: (Narration) We sailed our maiden voyage on the Nile, with an inexperienced and good natured crew of tour guides from the exhibits, using makeshift paddles.

HARRY TZALAS: Wahad, igneen.

ALAN ALDA: (Narration) Harry couldn't resist trying to impose proper naval discipline.

HARRY TZALAS: They never learn how to paddle and the paddles are so bad that it's a miracle that they are moving it. But the craft is very, very good. It has a very good buoyancy and it will go very fast, faster than the papyrella.

ALAN ALDA: (Narration): So far so good. Our boat is stable, heavy, controllable, and maybe fast. Ours is not the first attempt to build a seagoing reed boat. In the 60s the Norwegian explorer, Thor Heyerdahl, built a huge boat intended to cross oceans.

NARRATOR: The papyrus boat moves in the shadows of the pyramids, first pulled by chanting Egyptians then carried on a truck the to Egyptian port of Alexandria and at last born by ship to the ancient Phoenecian port of Saffi, on the Atlantic coast of Morocco.

ALAN ALDA: (Narration) Heyerdahl's romantic ambition was to prove that ancient Egyptians could have sailed to the Americas. But it soon became clear that, while papyrus may be unsinkable, it's not really practical for long voyages. The reeds gradually became waterlogged. After 2 months at sea the boat was virtually underwater, and had to be abandoned. For its first sea trials, we've moved our boat to Alexandria, Egypt's ancient Mediterranean port. Harry believes this is the only kind of boat that could have been made with stone tools, that's big and stable enough to ride waves.

HARRY TZALAS: [Arabic]

ALAN ALDA: (Narration) The boat holds 8. The only problem is half are Greek, half are Egyptian, and they're all archeologists, anyway, so they can't agree on anything - until Harry's naval instincts take over. BOAT CREW: Hey-la-hup. Hey-la-hup. Hey-la-hup.

ALAN ALDA: (Narration) Was he happy so far?

HARRY TZALAS: Well it's good. It comes naturally you see they have not tried before and it goes so quickly. It's good.

ALAN ALDA: (Narration) Harry follows the reed boat to observe its behavior further out in the harbor.

HARRY TZALAS: They're doing well and although there is a strong wind, the boat has no problem at all. It can take any wind.

BOAT CREW: Hey-la-hup. Hey-la-hup.

ALAN ALDA: (Narration) After only an hour of work, our crew is moving at a respectable 2 miles an hour - enough to hop between Greek islands in a day, and then pull the boat up to dry out overnight. It's a safe and stable boat, easily capable of transporting obsidian from Milos, and even going further afield. It's better than the original papyrella Harry built.

HARRY TZALAS: With the papyrella you could go up to Milos and you can circumnavigate in the Cyclades. With that boat which we are using now in Alexandria, which is a little larger, a stronger craft, more perfections, I would not hesitate in saying that you can reach going coastal-coastal, you can reach Cyprus without a problem.

ALAN ALDA: (Narration) Harry believes it was islands beckoning on the horizon, and calm seas between, that made Greek strength in shipping inevitable. Today the ships are 1,000-foot steel giants, but in the Stone Age they were 20-foot papyrus reed boats.

HARRY TZALAS: Greece is a shipping nation because it has always been a shipping nation.

ALAN ALDA: (Narration) By 13,000 years ago, the valuable Milos obsidian had been discovered and brought back to the mainland - some of it to Franchthi cave.

HARRY TZALAS: There is a chain of seamanship that goes back to Franchthi. If you live around the Aegean with all these islands, that you can see these islands, then you become curious, then you become seamen, then you get a civilization and you export this civilization. Civilizations were not exported by road with horses and carts. All civilizations were put around the Mediterranean with ships.

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## COPPER ISLAND

The interior of the island of Cyprus. It would have been a vista of forests, a few thousand years ago. But the forests went up in smoke, burned in smelters to produce copper. The mines and smelters of Cyprus became the eastern Mediterranean's major source of copper soon after the beginning of the Bronze Age, 4,000 years ago. Bronze is 90% copper, so in some ways Cyprus was the foundation of the Bronze Age. Metal tools made sophisticated woodworking

possible, so sturdy, seaworthy traders like this were a common sight. She was built by Harry Tzalas in the 70s, based on a wreck from 300 BC discovered here at the port of Kyrenia on the Cyprus coast. A local sponge diver's chance discovery and the subsequent excavation had yielded enough information to make an exact replica. Harry found she sailed beautifully. So, no secret about how Cyprus copper had reached the farthest corners of the Mediterranean. But back on shore things aren't quite so easy.

ALAN ALDA: What went wrong here?

WALTER FASNACHT: Something went wrong that the tube was plugged and now I have to exchange it because I broke it.

ALAN ALDA: One of these pipes down there?

WALTER FASNACHT: So we have these two pipes. They put the air into the furnace via two tuyeres.

ALAN ALDA: (Narration) Swiss archeologist,

WALTER FASNACHT:, and his students have an emergency on their hands. They're trying to smelt copper in a replica ancient furnace, and they've just broken a tuyere - the clay nozzles that squirt air into the furnace. Here's one part of the broken tuyere. The other has to be fished out. The end melted after it was blocked by slag and overheated - Walter should have been keeping it clear.

ALAN ALDA: The fact that the other nozzle melted means that you're already above 1200 degrees?

WALTER FASNACHT: Yes. Right.

ALAN ALDA: So what does that tell you? When you're above 1200 degrees, what happens?

WALTER FASNACHT: Well, it is forming slag. So the process should be going on and it looks good for the process. We just had this little accident.

ALAN ALDA: (Narration) Once the new tuyere's installed, it's time to check the other one - without breaking the end off this time.

WALTER FASNACHT: I have to punch it and - watch out - very carefully. So. And this is the slag that forms.

ALAN ALDA: Tell me Walter, you think they had emergencies just like this all the time in antiquity?

WALTER FASNACHT: This accident probably wouldn't have happened to them because they wouldn't have been talking to TV crews for an hour.

ALAN ALDA: Well, you haven't found any remains of TV crews. You really don't know.

ALAN ALDA: (Narration) In 1989, Walter, an expert on ancient metals, uncovered the only complete copper-working site ever found in Cyprus. There were two broken smelters, made of clay. There were sections of furnace wall, burned on the inside. This is a solidified puddle of slag, the waste product from smelting. He found charcoal fuel. And sections of round clay pipe, like the one Walter broke. There was also a large, clay-lined pit, and nearby, a source of copper ore. Walter decided the only way to fully understand the discoveries was to try reproducing how they worked, on the hill beside the ancient site. First the ore is crushed. It's chalcopyrite, a mixture of copper, iron and sulfur - the most common copper ore. Next, fire up the open clay pit. It's a half-scale model of the clay pit excavated on the site. Analysis of the ancient residues showed that the pit was used for low-temperature roasting, which drives off some of the sulfur in the ore. Walter has to bring in charcoal, that would normally end up in vacation barbecues. The finely crushed ore, held together with a little clay, is roasted for several hours. This step will remove the sulfur attached to the iron. The red color shows that has been accomplished. But there's still sulfur attached to the copper. Burning that off is the next step. We're going to need high temperatures, and that means a forced draft, from leather bellows. Bellows were common throughout the ancient world. Walter found pieces of the clay bases and tubes, so he's pretty certain this is how they were made here. The goal is to both burn the sulfur off the copper, and at the same time melt sand with the iron to make slag. That'll take temperatures inside the furnace of over 1200 degrees Celsius, sustained for at least 6 hours. There's a lot of pumping to be done.

ALAN ALDA: Can I try it if I'm really careful?

WALTER FASNACHT: Yeah. Sure, sure. Oh, that's very good.

ALAN ALDA: You've got to open and close in rhythm.

ALAN ALDA: (Narration) In goes the first charge of roasted ore, now crushed with a little sand. We'll be steadily adding charcoal and ore throughout the day. It's a pretty elaborate recipe, so I had a question for Walter.

ALAN ALDA: How did all these things come together? How did early people arrive at this complicated process? How did they know they were going to get copper out of this process?

WALTER FASNACHT: To begin with, they had blue or green copper mineral, 10,000 years ago. They found this nice colored stone and they fiddled around with it-made nice jewelry and then it fell into the fire and melted and gave them copper.

ALAN ALDA: (Narration) Well that's OK for the simple copper ores that smelt easily. But for the stuff we're using, people must just have found it so attractive that they believed it was worth experimenting a lot until they got results. It's now the end of the day. Time to see how we did.

WALTER FASNACHT: I will have to take this whole lump out as an entire unit. I hopefully succeed. I'll just try it with this shovel. Watch out!

ALAN ALDA: If this is the way you want it, what do you do with it next?

WALTER FASNACHT: If it's the way I want it, we have to separate the slag from the matte.

ALAN ALDA: (Narration) Here's the lump cut in half. At the bottom is the matte - about 60% copper, double what we started with. Next, the slag at the top would be removed and the matte re-smelted, a step Walter has not yet tried. In fact this was only the third smelting trial he's done here. So skipping ahead, Walter set out to actually make something out of bronze, which is copper with a little tin added as a hardener. In antiquity the tin would have come from the mainland. We cheated - our bronze was factory made, but the melting technique is authentic. The aim is a rapid, high-temperature melt, then an immediate pour before the tin burns off. Charcoal keeps the heat in, but it mustn't contaminate the metal.

WALTER FASNACHT: It's a crucial moment now. If I miss it, we burn the metal and then you're in trouble. Yep, it's liquid.

ALAN ALDA: (Narration) There's still a lot of charcoal in the crucible. We're making astragali, dice shaped like the heel bone of sheep or goats.

WALTER FASNACHT: So. This one is quite okay. And this one has a lot of charcoal in it. This one they would consider as a failure. They would re-melt this.

ALAN ALDA: I thought these would have numbers on them or are there numbers? I can't tell.

WALTER FASNACHT: You have to know the numbers in your head.

ALAN ALDA: Oh, I like dice like that. You throw a couple of blank dice, you say, I remember where the numbers were and I got a 7.

WALTER FASNACHT: Whenever you see these two horns, that's the number 4.

ALAN ALDA: I see.

WALTER FASNACHT: And this round part is the number three.

ALAN ALDA: I see.

ALAN ALDA: (Narration) You need 5 astragali for an ancient Greek fortune, so we threw real sheep bones.

ALAN ALDA: I can't tell what these numbers are.

WALTER FASNACHT: Four, four, three, four, three. Twelve and six-eighteen.

ALAN ALDA: So now the high priest would look it up on his Xeroxed sheet, right?

WALTER FASNACHT: It was hammered into stone. They would write the text into stone.

ALAN ALDA: So, that's how we come to know what the meaning is.

WALTER FASNACHT: Yes, yes. When 3 fours as well as 2 threes fall-wait! You will have success but only later. For now stay quiet. Obey the gods and be awaiting.

ALAN ALDA: I think I need to throw again. I need a little more immediacy here.

WALTER FASNACHT: But watch out! There are also less comfortable ones.

ALAN ALDA: Less good ones? Here, thanks very much.

ALAN ALDA: (Narration) The next day, fortune smiled on us. Walter made a perfect set of bronze astragali on his Cyprus hillside.

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THE SEA WITHIN THE SEA

ALAN ALDA: (Narration) We're in Sardinia, the Mediterranean's largest island. It's the village of Stintino's annual "sagra". The sagra, or celebration, is for the arrival of the tuna. Celebrations like this have been held around the Mediterranean for as long as people can remember. In June, when the giant bluefin arrive off the coast to spawn, celebrating the bounty of the sea brings the whole village together. But like fisheries all over the world in recent years, tuna catches have been dropping alarmingly. So now there's an urgent need to understand and protect the region's marine life - not least because in so many places it's not just marine life that's threatened, it's community life. The focus is on an area just north of Sardinia, the Ligurian Sea. As of 1999, it has contained the world's first international marine reserve. The waters are the most productive in the Mediterranean, attracting in summer large numbers of dolphin, tuna and whales, coming in to feed. It's August in the Ligurian Sea, and we've joined an Italian government research team looking for some of the area's most elusive inhabitants - fin whales. The Mediterranean has a lot of fin whales, about 4,000 it's believed. We know they concentrate here in summer, but not much else.

CHRIS CLARK: Two... We got them three at three o'clock.

ALAN ALDA: (Narration) Two American whale sound experts are visiting the team.

CHRIS CLARK: It's like when you see whales you go, Did I actually see something? Are they really there? Wow, yeah. Boy, they're moving. Rapido!

FABRIZIO BORSANI: The problem is that the whales are too fast for us. When they speed up they go faster than ten knots.

ALAN ALDA: (Narration) Just ahead of the boat, the whales dive.

FABRIZIO BORSANI: They usually stay down for about 10 minutes. So it's 7 minutes they have been down now.

CHRIS CLARK: Look at that. Fantastic. Holy cow.

ALAN ALDA: (Narration) These 100-foot giants are found worldwide, but they were never hunted in the Mediterranean so the population should be healthy. Our whale swims under the boat at 18 meters - 50 feet - depth.

CHRIS CLARK: Beautiful. Look at him. 18 meters, huh...

FABRIZIO BORSANI: Yep. She passed underneath us. And now the second one is here, to the right side of the boat, about 10 meters.

ALAN ALDA: (Narration) It's a rare and lucky encounter, so Chris and Fabrizio try listening for sounds. Fin whales have never been recorded in the Mediterranean.

CHRIS CLARK: If you listen every now and then you hear that - just a little bit of modulation in the tone.

FABRIZIO BORSANI: It's too short.

ALAN ALDA: (Narration) They weren't quite sure what they were hearing, and within 45 minutes the whales had vanished.

CHRIS CLARK: In the life of a whale, or in the day of a whale, 45 minutes is nothing. You really need to listen over much, much longer periods.

ALAN ALDA: (Narration) Chris Clark and

TOM CALUPCA: have brought on board underwater sound recorders they designed to be left behind, to run continuously for weeks. The night before deploying the recorders, Fabrizio had to coordinate things with the local fishermen.

FISHERMAN: [Italian]

FABRIZIO BORSANI: This fisherman just told us where they trawl on the bottom at 500 meters so that we can choose a location that we're going to tell them where we are going to place to pop-ups.

ALAN ALDA: (Narration) They're called pop-ups because the recorders will float up from the sea floor on command. The team is putting out 2 pop-ups - and it's the first time they've tried.

CHRIS CLARK: We've got a problem. Let it go!

ALAN ALDA: (Narration) The pop-up drops abruptly into the water, but nothing seems to break and a few minutes later a solid acoustic communications link is established with it.

TOM CALUPCA: The three long beeps, that means the pop-up recognized, understood the message OK.

ALAN ALDA: (Narration) Finally the pop-up is released to sink gently to the bottom, 1500 feet below. We're with another Italian team, that recently made a surprising discovery about Mediterranean fin whales. Tiny skin samples were

collected and analyzed. They showed that Mediterranean fins are genetically isolated - they're on their own.

FABRIZIO BORSANI: No genes of the Mediterranean whales have been found in the Atlantic and vice versa, which speaks loudly for a resident population.

ALAN ALDA: (Narration) If fin whales are resident here, that means they're especially vulnerable to the Sea's crowding and pollution. It's essential we learn more about these whales, so we can safeguard their future. It's Fall, and the team is heading out to collect the pop-ups. With winter coming, it's thought the whales will already have left. Tom will dial up the pop-up on the sea floor, telling it to release its ballast weights.

TOM CALUPCA: There it is! The buoy's at the surface. It's right over here - just off the boat, about 50 meters away. We're in a good spot.

ALAN ALDA: (Narration) It's a little like a spacecraft splashdown, and in truth the pop-up has just returned from a largely unexplored place.

TOM CALUPCA: Nine oh nine and thirty seconds - now. Welcome home!

ALAN ALDA: (Narration) The pop-ups brought another surprise result - clear recordings of lots of whales in the Ligurian Sea, right into winter. We never knew they stayed, and in fact all other fin whales in the world migrate. ACTOR: (sub-titled) They're coming. The tunas are coming.

ALAN ALDA: (Narration) These are scenes of a real bluefin tuna "mattanza", or "killing", shot in Sicily in the 1940s. There's no better evidence of the tremendous abundance the Mediterranean yielded. But catches like this haven't been seen in decades. We're back in Sardinia, for the 1999 mattanza near the village of Carloforte. We're not here to catch tuna, but to tag and release them. The tags are satellite transmitters that will drop off in a few weeks and signal their positions. The question is the same as with the whales - Are the tuna Mediterranean fish, or Atlantic fish, or both? It's pretty rough above, but tranquil below. There are enough fish in the net for a few tags. In 2 years so far, 10 tags have been successfully tracked. They seem to show there are distinct groups of Mediterranean and Atlantic tuna. We have to understand these populations soon, to work out how to regulate the catch before relentless fishing pressure overtakes the species. The wonderful Mediterranean fin whales are not yet in trouble, so far as we know. But with the Sea's tuna and turtles under stress, and with the looming caulerpa invasion, the Mediterranean offers one of the world's clearest challenges to our ability to live alongside nature. And meanwhile, don't forget about preserving our human heritage around here, too. That's all for this edition. See you next time.

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