stripe

Project Vesta

APPLICATION FOR STRIPE 2020 NEGATIVE EMISSIONS PURCHASE

Section 1: Project Info and Core Approach

1. Project name

Project Vesta

2. Project description. ***Max 10 words***

Accelerate olivine weathering with wave power for carbon dioxide removal.

3. Please describe your negative emissions solution in detail, making sure to cover the following points:
   a) Provide a technical explanation of the project, including demonstrations of success so far (preferably including data), and future development plans. Try to be as specific as possible: all relevant site locations (e.g. geographic regions), scale, timeline, etc. Feel free to include figures/diagrams if helpful. Be sure to discuss your key assumptions and constraints.
   b) If your primary role is to enable other underlying project(s) (e.g. you are a project coordinator or monitoring service), describe both the core underlying technology/approach with project-specific details (site locations, scale, timeline, etc.), and describe the function provided by your company/organization with respect to the underlying technology/approach.
   c) Please include or link to supplemental data and relevant references.

Max 1,500 words *(feel free to include figures)*

Project Vesta is working to establish enhanced coastal weathering as a new negative emissions category with nearly limitless carbon dioxide removal (CDR) potential.

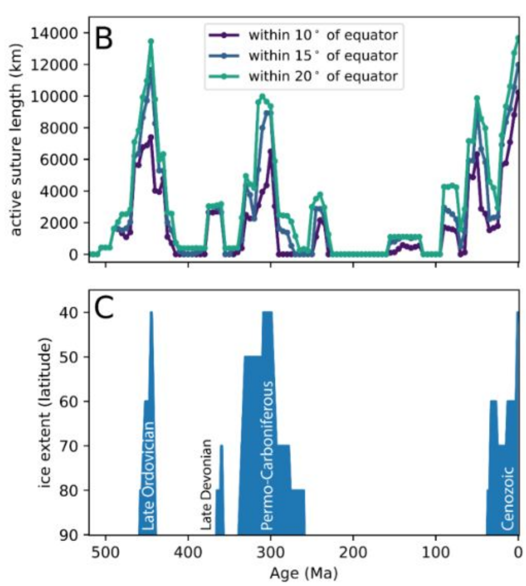
This project removes carbon dioxide from the atmosphere/oceans by utilizing enhanced weathering to turn CO_2 into the carbonate molecules that corals use in their shells. This long-term carbon cycle is Earth's natural process for removing the CO_2 emitting by volcanoes. This process of chemical weathering of carbonate and silicate minerals has led to [99 9%] of carbon on Earth to become stored in solid form as rocks and sediment, as exemplified by the [White Cliffs of Dover].

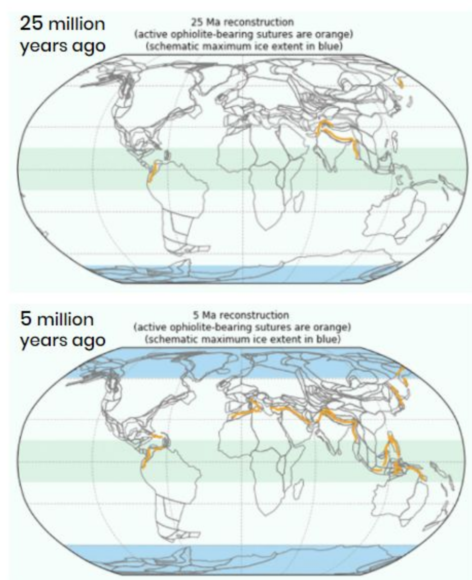
Estimates of the relative distribution of carbon on Earth, in kg and % (after Berner and Lasaga, 1989).

Calcium Carbonate	35,000 *	46.64%	79.99%	
Ca-Mg Carbonate	25,000	33.31%		99.94%
Sedimentary Carbon (Kerogen & Graphite)	15,000	19.99%	19.99%	
Recoverable Fossil Fuels	4	0.0053%		
Oceanic $HCO_3^- - CO_3^{=}$	42	0.056%		
Dead Surficial Carbon (Humus and Peat)	3	0.0040%		0.06%
Atmospheric CO_2	0.72	0.00095%		
All life	0.56	0.00074%		

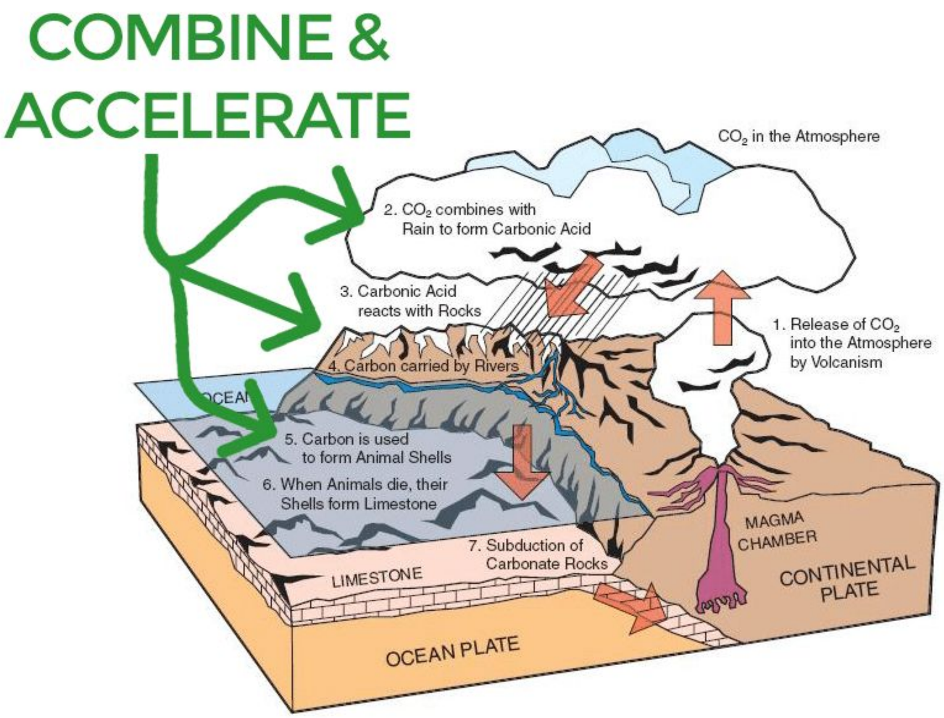
*Kg x 10^{15}

At certain times in Earth's geological history, tectonic forces have by chance exposed so much weatherable silicates and carbonates in the humid tropics around the equator, that the resulting weathering reaction removed enough CO2 that it led to global coolings and increased ice coverage on the poles. A growing body of research points to these "[arc-continent collisions in the tropics set[ing] Earth's climate state.]"

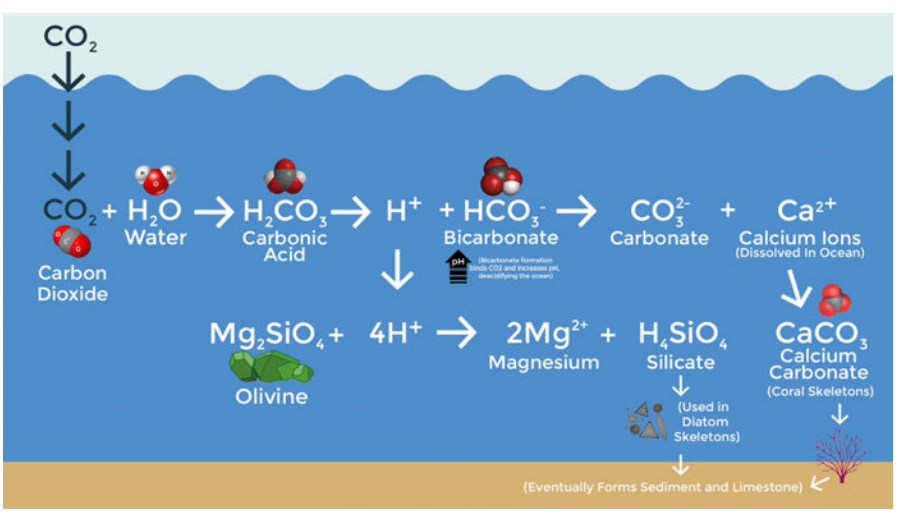




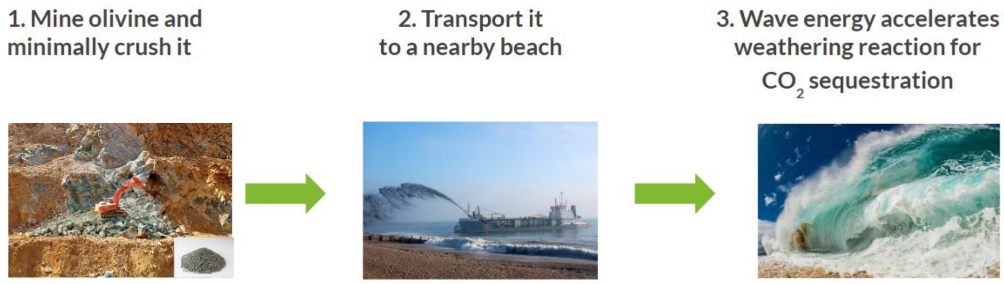
Project Vesta takes inspiration from Earth's natural biogeochemical mechanism for global scale carbon dioxide removal (CDR). However, because humanity does not have millions of years to wait for chance collisions of the right rocks to occur in the right places, we instead plan to combine and accelerate the steps of the process that results in the CO2 removal, from the exposure of the rock to water its transport to the ocean.



The chemical reaction to "remove" and store CO2 is as follows: Atmospheric carbon dioxide (CO_2) enters the surface ocean and dissolves in the seawater. Dissolved CO_2 converts into carbonate ions (HCO_3) and free protons (H^+). This causes the pH to decrease, and can contribute to counteracting ocean acidification. The olivine dissolution reaction in turn consumes protons from the aqueous medium (Fig below). By consuming the protons, the olivine mineral matrix breaks down and releases metal ions (Magnesium, Mg) and silicate ions (H_4SiO_4) into solution. For every molecule of olivine dissolved, between 3 and 4 protons are removed from the seawater. By removing protons from the seawater in the dissolution reaction, the acidity (pH) decreases, while the alkalinity (acid buffering capacity) increases. This has been demonstrated under controlled lab conditions ([Montserrat et al 2017](#)), and even in mesocosm setups (Montserrat et al, in progress). However, up until now, no projects have attempted to directly accelerate this process under natural (field) conditions.



Project Vesta's plan is to efficiently accelerate the weathering reaction and CO_2 removal aspect of the long term carbon cycle by placing the fastest weathering silicate, olivine, directly into warm, high-energy coastal environments. In the "**beach application**" scenario, olivine sand is mined from nearby reserves (within 300 KM) and distributed onto beaches and shallow subtidal areas. The dissolution of olivine particles in these shallow waters is greatly enhanced through wave action (stimulating grain collisions and surface abrasion) as well as through various forms of biological activity in the seabed. Such coastal olivine deployment could be advantageously integrated into various existing forms of coastal zone management (e.g. harbor construction works, sand nourishment on beaches, restoration of degraded coral fields).



Previous proposals for large-scale enhanced weathering on land or through open ocean alkalization are hamstrung by fundamental speed and efficiency flaws. On land, the olivine is stationary and a coating of silica builds up that dramatically slows the reaction. For ocean alkalization, the particles have to be small enough that they are able to weather before reaching the deep sea floor where it is cold and it will become stationary. To grind olivine to the micron level where it rapidly weathers is normally too energy intensive to make either of these processes viable, however, by utilizing the power of wave energy to finely mill coarse olivine from nearby reserves, our process is able to remain highly efficient. (See Question 7). As the underlying stoichiometric chemistry for the dissolution of 1 tonne of olivine resulting in up to 1.25 tonnes of CO2 is valid, the main question to demonstrate is whether wave motion and warm acidic water are able to significantly accelerate the weathering rate of olivine.

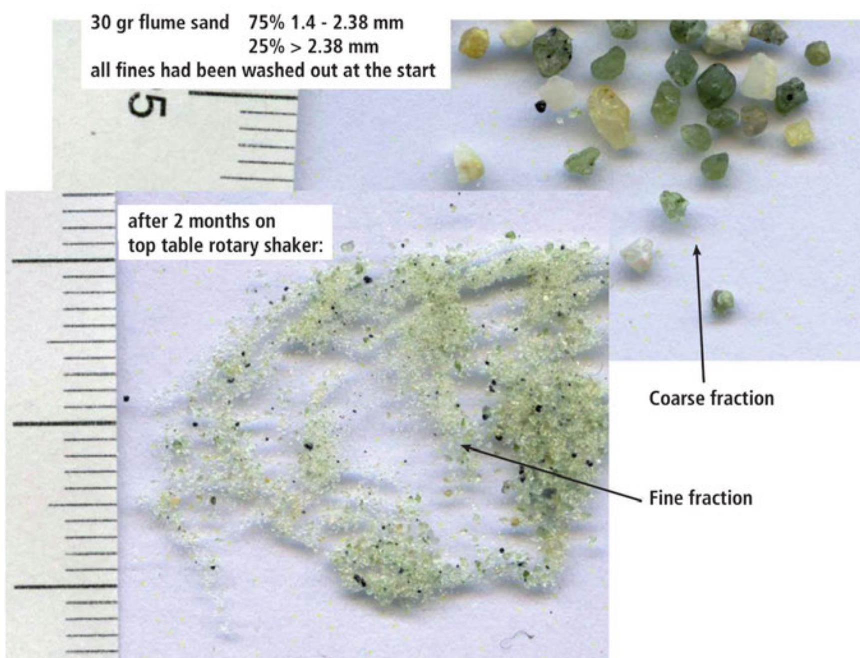


Table top shaker experiments have demonstrated that the forces of grain-on-grain collisions create fine fraction grains in relatively brief timescales and that motion is crucial in accelerating olivine dissolution. The above photo is of olivine grains after two months of shaking coarse grains sizes of 75% 1.4mm to 2.38 mm and 25% > 2.3 mm. After this short period of time, the grains are nearly all fine fraction of the size that weathers extremely rapidly.

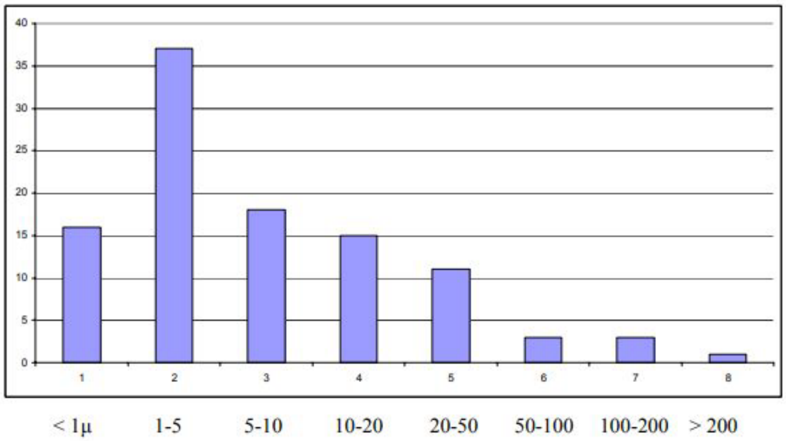
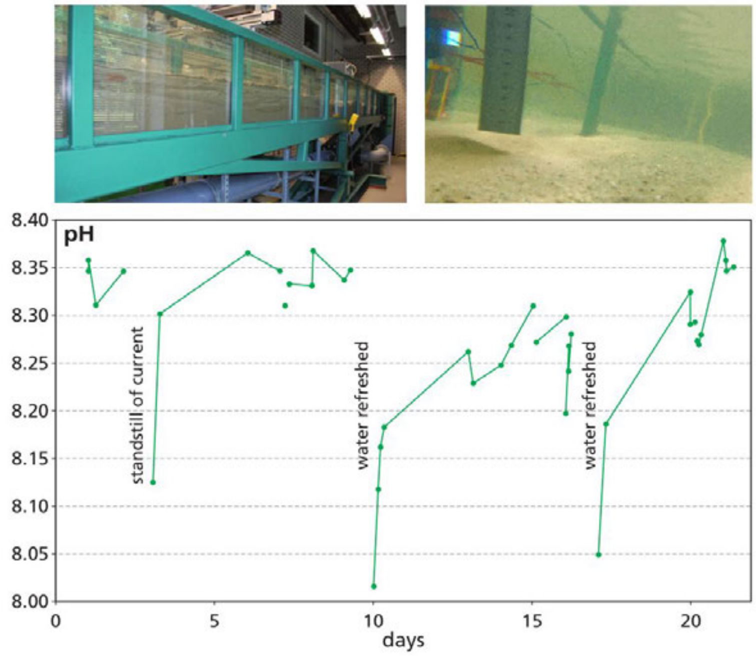


Fig. 3. Size distribution of the olivine scraps after 12 days of continuous motion on the table top rotary shaker. Scale in µm. Total weight 9 g. Original sample 30 g.

A different table top shaker experiment containing 30 grams of olivine of material 50% 0.71-1.4 mm & 50% 2-5 mm grains, showed that after 12 days, 30% of the 30 grams had weathered to fine fraction less than 200 microns, with more than 50% of the fine fraction below 10 microns (pictured above).

The other major effect of motion on weathering rate is the effect of motion on surface abrasion. When olivine chemically weathers, the reaction causes a silica coating to quickly build up on the surface of the grains. In stationary applications, this coating significantly slows and can even inhibit the reaction. In the above “before” and “after” images, you can see how after 3 days, the 2-5 mm grains with the yellow dashed lines have been made smooth through collisions, this process also removes the silica coating on the surface (represented with the dashed yellow lines).



Flume experiments have quantified the effect of motion on olivine weathering and dissolution kinetics by putting the olivine in motion and measuring the change in pH as a proxy for the weathering reaction. In the above chart, broken lines represent times when the water was stopped. When the olivine is in motion and surface abrasion is occurring, the pH rapidly rises. When the water stops, as CO2 continues to enter the top of the flume, the pH drops back down. Once the motion begins again, the pH continues to rise. This demonstrates clearly that motion is essential to accelerating the olivine weathering reaction and also that the resulting reaction is able to deacidify the water as the olivine binds to the CO2 dissolved in it.

By accelerating Earth's natural process of CO2 removal these and other experiments have demonstrated that enhancing the weathering reaction of olivine has the potential to remove global scale CO2 emissions, while helping to deacidify the ocean on human timescales.

However, due to the lack of proprietary technology with the underlying natural process, commercial investments in this field have been lacking. Further, the research institutions of the world have failed to fund the science to close the gap between feasibility of the process by deploying real-world, in situ pilot projects.

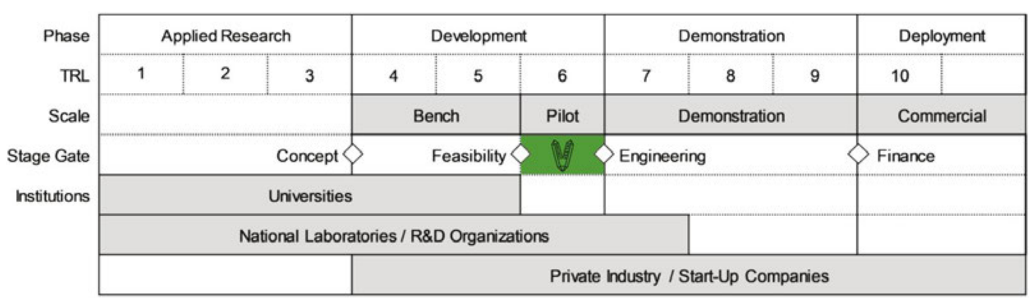
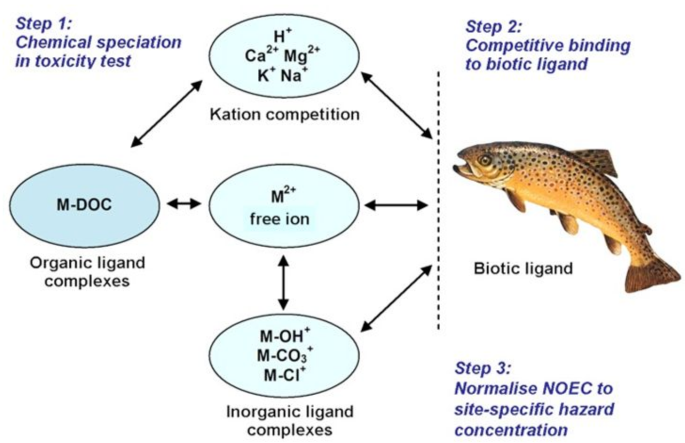


FIGURE 1.7 Illustration of coordination between research phases, technology readiness level (TRL), prototype scale, stage-gates, and institutions.

Project Vesta, a non-profit organization, was created to bridge this gap and carry out the projects needed to advance the science to a deployable and financeable level. Before large scale deployments for CDR can proceed, pilot projects are required to quantify the accelerated weathering rate in the real world and ensure the safety of the marine environment. Our overall goal is to bring forward the entire category of enhanced coastal weathering on the technological readiness scale (Figure 1.7 above) and unlock the entire "enhanced weathering" category for global scale CDR. For the last 10 years, enhanced coastal weathering has been stuck on Level 5, with a lack of funding for the large scale, real-world pilot projects required to demonstrate the actual weathering rate, safety, and life cycle efficiency of the process from quarry to beach to bicarbonate. We are taking that first step to advance the enhanced weathering field with our Phase Ia Pilot Safety Study. While it is primarily designed to determine the safety of the release of precipitants from the reaction, the olivine on the beach will be weathering and is available for negative emissions credit purchases.

Before large-scale deployments can go forward, we must prove the safety of the process and verify the hypothesis that adding olivine to an existing ecosystem will not cause harm from any of the precipitants, including heavy metals such as nickel that can be contained in the crystal lattice of the olivine. Project Vesta's lead scientists and partners include ecotoxicologists and some of the world's top researchers on heavy metal release from olivine. Our partners at Deltares, a Dutch non-profit research consultancy for water, soil, and subsurface, have publicly released a model called PNEC-pro that is approved as a second-tier assessment for determining site-specific ecotoxicological risks to aquatic species based on the bioavailability of heavy metals. (See: Section 6)



The hypothesis of our expert panel is that while heavy metal may be released into the water, the heavy metals will quickly bind into forms that are not bioavailable to animals in the ecosystem. The existing models need to be adapted for ocean use and we will use our data to help optimize these open source models to generate one that can quantify a rate at which olivine can safely be added to the environment. Data gathered from research on the corals in the natural olivine beach in Hawaii, Papakōlea, has determined that the local corals and ecosystem are unaffected by the release of precipitants from olivine weathering. We are a “safety first” organization which is why we are testing safety before speed with our Phase I Pilots. We want to ensure that adding olivine to a new environment will not have a net-negative effect on the ecosystem (only on CO2).

The Phase Ia study will consist of two similar bays located in close proximity to each other, where one bay will serve as the control and the other as the experiment. Bays have been selected for this experiment because we want a slower refresh rate of the water so that precipitants can build up to higher levels than they normally would on an open coastline. This makes the data easier to attain and will give us a “worst” case scenario of precipitant buildup. The beaches selected for the project are located in the Caribbean in a currently publicly undisclosed location. We are working hand-in-hand with the local government to deploy the project. The beaches are remote, but we are working with the nearest villages to ensure their informed consent is attained and we are further working to hire their residents to help with security and eventually, the last-mile delivery of the olivine sand among other tasks. We have surveyed and sampled the bays and beaches, and they meet the requirements for our project. A further benefit is that there is a high-energy beach nearby (top left of image) where we could carry out the Phase Ib speed study soon thereafter.

The experimental setup and monitoring scheme will adhere to a Before-After Control-Impact (BACI) design. In this manner, any measured effects can be unequivocally attributed to the olivine application. We are deploying long term monitoring equipment to both bays to determine the baseline signal and to ensure the conformity of the characteristics of the two bays. Geochemical flux measurements are required to measure the olivine dissolution rate, to effectively convert it into carbon credits. Some proxies for measuring olivine dissolution are:

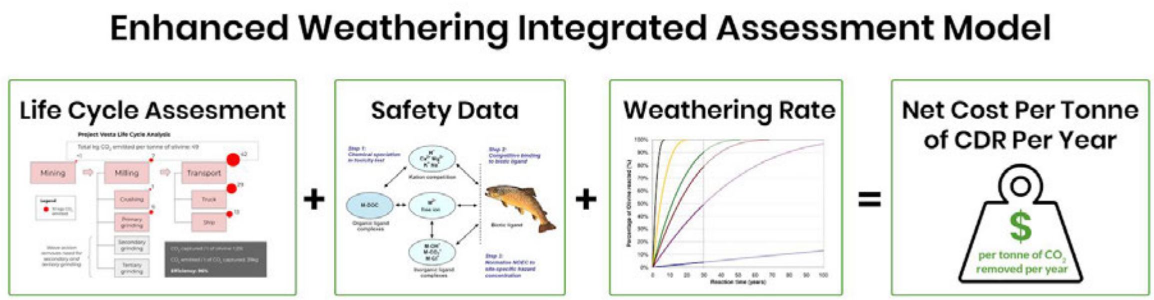
- Dissolved Silicate
- Dissolved Nickel
- Total Alkalinity (TA)
- Dissolved Inorganic Carbon (DIC)

Flux measurements of reaction products (above) over the sediment-water interface (SWI) are to be done both in situ and ex situ, by extracting sediment (with added olivine) from the system and incubating them in the lab.

The compartments of the ecosystem that need to be sampled are:

- Overlying water
- Sediment solid phase
- Sediment pore water
- Biota encountered in the ecosystem

Once sufficient data has been acquired, we will begin deploying a layer of olivine sand to the bay on the right (outlined in green above). All of the deployed olivine will be available for purchase as net-negative emissions credits and the rate at which they weather will be quantified in the experiment.



This Phase Ia Pilot is a key part of our plan to bring enhanced weathering in the coastal zone to the fore as an entirely new category of carbon dioxide removal with nearly limitless upscaling potential. To this end, a key deliverable from our Phase I Pilots will be an Enhanced Weathering Integrated Assessment Model (EWIAM) that future enhanced weathering projects will be able to utilize. Based on a project's specific inputs, the model combines the Life Cycle Assessment, Safety Data, and Weathering Rate, and returns a project specific cost per tonne of CO2 removed per year. We plan to release this model to the world in an open-source way so that it can be verified by the science community and certified for net-negative emission purchases. The acceptance of the EWIAM for CDR has the potential to spur the formation of a gigatonne scale market for enhanced weathering CDR projects. Your purchase of our net-negative emission credits will help fund the formation of this model.

Low cost	$10 / tonne at scale;
Permanent capture	Carbon is locked up in limestone for 100s of millions of years
Increases in efficiency	The warmer and more acidic the oceans get, the faster the chemical reaction happens
Avoids land use conflicts	Does not compete with agriculture or neighbors for land use; Vesta beaches can still be used by people and wildlife
Globally scalable	Feasible all over the world; can be scaled up to capture significant proportion of human emissions
Simple	No development of new technologies required
Modest capital cost	Can be achieved by leasing existing mining and transportation machinery
Set and forget	Once the rocks are deployed, no maintenance
Modest energy cost	Natural wave energy does most of the work; 20x return on CO_2 emitted in deployment process
Ancillary benefits	De-acidifies oceans as well as capturing CO_2

Olivine is one of the most abundant minerals on Earth, making up over 50% of the upper mantle. A volume of less than 10 KM^3 on 2% of the world's shelf seas has the potential to offset all of humanity's yearly CO2 emissions. Coastal enhanced olivine weathering is permanent, cheap, scaleable, and does not compete for arable land, fresh water, or other limited resources. It is future proofed against a worse climate because as the planet gets hotter and/or the oceans more acidic the weathering process speeds up. For these reasons and more we believe coastal enhanced weathering needs to be fully developed and deployed, and this pilot Project is the first step in taking this CDR technique [from the lab to the beach](), and eventually to the world.

Section 2: 2020 Net-Negative Sequestration Volume

See Stripe Purchase Criteria 1: The project has volume available for purchase in 2020.

4. Based on the above, please estimate the **total net-negative sequestration volume** of your project (and/or the underlying technology) in 2020, in tons of CO_2. (Note: We're looking for the net negative amount sequestered here, net lifecycle emissions. In Section 3; you'll discuss your lifecycle and why this number is what it is).

200 tonnes

5. Please estimate how many of those tons are still available for purchase in 2020 (i.e. how many tons not yet committed). This may or may not be the same as the number above.

200 tonnes

6. (Optional) Provide any other detail or explanation on the above numbers if it'd be helpful. ***Max 100 words.***

The entire amount of olivine that will be placed in our embayment is available for purchase for offsetting purposes.

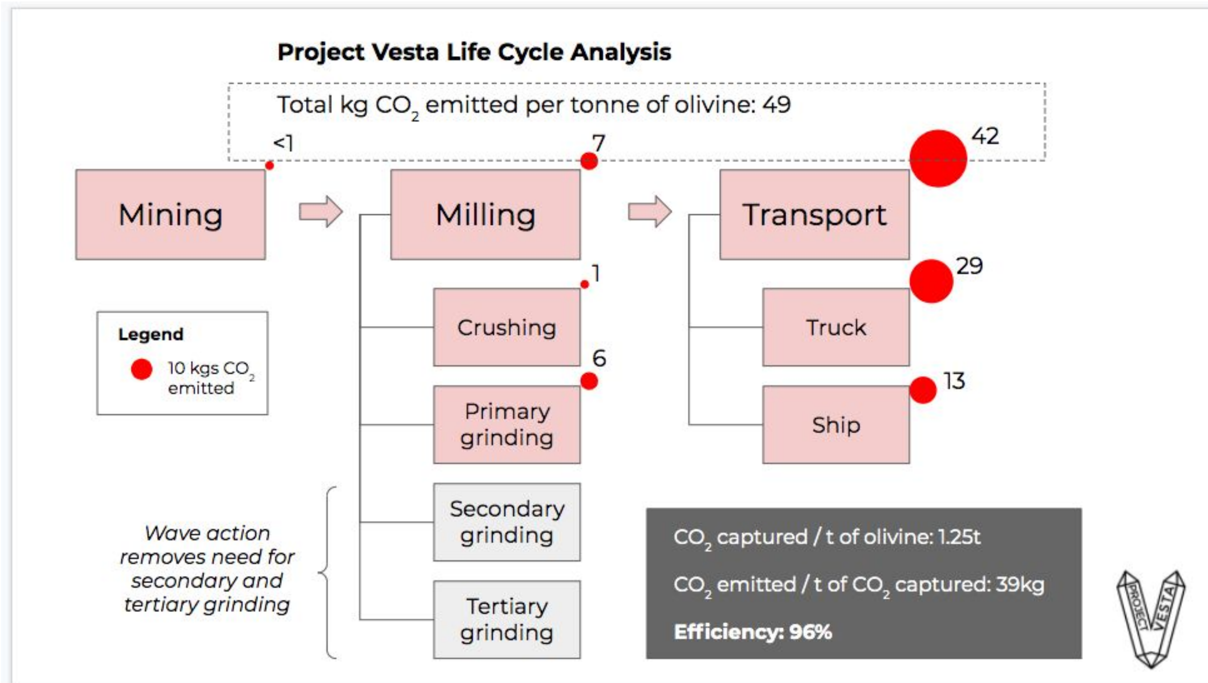
Section 3: Life Cycle Analysis

See Stripe Purchase Criteria 2: The project has a carbon negative complete lifecycle (including energy use, etc).

7. Provide a life cycle analysis of your negative emissions solution demonstrating its carbon negativity, as complete as possible given limited space, and making sure to cover the following points:

a) Include a flow sheet diagram of direct ingoing and outgoing flows (GHG, energy, materials, etc) that bear on the LCA.
b) Please be explicit about the boundary conditions of your LCA, and implications of those boundaries on your life cycle. Let us know why the conditions you've set are appropriate to analyze your project.
c) Make sure to identify assumptions, limitations, constraints, or factors that relate to ingoing and outgoing flows, citing values and sources (for example: land and resource scarcity, limitations on a required chemical, energy requirements). Also identify key sources of uncertainty in determining these values.
d) If your solution results in non-CO2 GHG emissions, please be sure to separately specify that (e.g. in units of GWP 20 or 100 years, ideally both).
e) For solutions that rely on modular components (for example: incoming energy flows or outgoing CO2 streams), feel free to cite values associated with those interfaces instead of fully explaining those components. For these values, please identify the upstream and downstream life cycle emissions of the component.
f) Explain how you would approach a more comprehensive LCA by citing references and underlying data needed for the analysis.

Max 1,000 words *(feel free to include figures or link to an external PDF)*



a) Boundary conditions:
   i) In Project Vesta, olivine is ground down using the initial stages of milling, requiring only relatively energy-inexpensive crushing and primary grinding. The far more energy-intense steps of secondary and tertiary grinding, which are necessary to create granules small enough for carbon capture on timescales measured in years, happen using natural wave energy in the ocean. Land-based olivine projects need secondary and tertiary grinding, which require 1-2 orders of magnitude more energy input than crushing and primary grinding.
   ii) Note: extracting the olivine from mines results in negligible carbon emissions compared with milling and transport
b) Assumptions, limitations, constraints, sources
   i) All Project Vesta GHG emissions come from the use of energy in mining, milling, and transport. There are no other gases released and no emissions from manufacturing or plant-building.
   ii) We assume the olivine will be ground to 100-300µm granule size
   iii) We assume transportation distance of 150km by truck and 1,200km by ship
   iv) Limitations & constraints
      1) The quantity of olivine available is not considered a limiting factor
      2) Mining and transportation infrastructure are available at large scale and are not considered limiting factors
      3) Theoretically, beaches and shelf seas are also in excess, but here we need permission from governments to deploy at sites on and adjacent to their countries. This creates a limitation on the speed at which we can roll out deployments.
   v) Sources of data
      1) We are working with scientists and engineers from various institutions including Utrecht University, Deltares, and others. All of our assumptions come from the various papers that have been written and published in the field of weathering. These are available for download on our website or on request.
c) N/A
d) N/A
e) A more comprehensive LCA will encompass the varying mining requirements of particular olivine deposits and would be specific to particular deployment sites. For example, an LCA of our initial sites in the country where our Phase Ia trail is, we will consider the mineral composition there to determine mining costs, the shorter transportation distance, and various other local factors.

External Sources:
Environmental life cycle assessment of CO2 sequestration through enhanced weathering of olivine [PDF]
Potential and costs of carbon dioxide removal by enhanced weathering of rocks [PDF]
Geoengineering potential of artificially enhanced silicate weathering of olivine [PDF]

8. Based on the above, for your project, what is the ratio of emissions produced as any part of your project life cycle to CO2 removal from the atmosphere? For true negative emissions solutions, we'd expect this ratio to be less than 1.

.04-.05

Section 4: Permanence and Durability

See Stripe Purchase Criteria 3: The project provides durable, long-term storage of carbon.

9. Provide an upper and lower bound on the likely durability / permanence of sequestered carbon provided by your project, in years:

100,000-100,000,000

10. Please provide a justification for your estimates, and describe sources of uncertainty related to: the form of storage, effects of environmental or climatic variability, difficulty in monitoring or quantification, etc. Specifically, discuss the risks to permanence for your project, the estimated severity/frequency of those risks (e.g. 10% of the acres of forest in this forest type are burned by fire over a 100 year period), and the time-horizon of permanence given those risks.
Max 500 words

The chemical reaction used by Project Vesta stores the carbon as bicarbonate in the ocean. This is considered permanent storage on any relevant timescale. Only if the ocean waters acidify even more (without additional buffer, like calcium carbonate or olivine), would the bicarbonate eventually convert back into CO_2 and outgas from the seawater. Much of the bicarbonate will follow its natural cycle and eventually end up as calcium carbonate in the shells and structures of marine organisms. When these organisms die and sink to the seabed, the sediment forms limestone, which then locks up the carbon for millions of years, until the rock is subducted and released in a volcanic reaction. The precise period the carbon is stored for is very hard to estimate given the extremely long timescales.

The process is "future-proofed" against increased global temperatures and rising acidity of the oceans. As atmospheric CO_2 increases, the oceans get warmer and more acidic, which in turn will cause faster weathering and thus counteracting the acidification. This balancing function of increased weathering caused by increased temperatures, humidity, and acidity, is why the long-term carbonate silicate cycle is known as the "global thermostat."

There are no known risk factors that create uncertainty about the permanence of Project Vesta's carbon capture.

Section 5: Verification and Accounting

See Stripe Purchase Criteria 4: The project uses scientifically rigorous and transparent methods to verify that they're storing the carbon that they claim, over the period of time they claim to.

11. Provide detailed plans for how you will measure, report, and verify the negative emissions you are offering. Describe key sources of uncertainty associated with your monitoring, and how you plan to overcome them.
Max 500 words

Laboratory experiments have shown empirically the stoichiometric assumption that 1 tonne of olivine, when it dissolves, captures 1.25 tonnes of CO_2.

While the extent of CO_2 sequestration is already well established and the available evidence suggests that the olivine will dissolve and complete its sequestration within 2-5 years, the exact rate of CO_2 sequestration on a real world beach remains a source of some uncertainty. The following approach will enable us to reduce that uncertainty as much as possible and establish a weathering rate model that can accurately predict the speed at which olivine weathers under varying natural conditions.

In the pilot project we are proposing, a relatively small embayment is used for deployment of ground olivine. As a control, another similar embayment in the vicinity is used, but without olivine addition. The experimental bay system is half-open, with limited seawater exchange with the open ocean. The considerable residence time of the water in the bay should enable us to measure accumulation of olivine dissolution products in the overlying water of the bay, on a timescale of days to months. Olivine dissolution rates will be quantified by open flux measurements. Over a period of days to weeks, the accumulation of various end-products of olivine dissolution (alkalinity (A_T), dissolved silicate (DSi), dissolved iron (DFe), trace metals) will be traced by monitoring the overlying water chemistry at regular time intervals. In addition, benthic chambers (a kind of upside down aquarium) are used to close off a part of the seafloor with seawater standing on top. In this closed off volume of seawater, accumulation of olivine dissolution products can be measured on a timescale of hours. These results can be used to extrapolate to, and checked against the results for the entire embayment. Water refreshment rates can be calculated and determined from local and historical data. To enable a full picture of geochemical cycling, water samples will be taken for a range of analyses, including nutrients (DSi, NO_3, NH_4, PO_4), anions (SO_4, Cl^-), metals (DNi, DFe, trace metals) and carbonate system parameters (see below).

CO_2 sequestration will be determined by monitoring the carbonate chemistry in the overlying water at regular time intervals. When Total Alkalinity (A_T) accumulates in the overlying water, there will be a transfer of CO_2 from the atmosphere, which increases the Dissolved Inorganic Carbon (DIC) concentration and pH. The carbonate system will be determined by simultaneously measuring the A_T, DIC and pH and verifying the consistency of the measurements using model simulations in the AquaEnv model framework (Hofmann et al., 2010).

Automated sensor platforms (temperature, salinity, pH, A_T, O2, and chlorophyll a) will be placed in the water at deployment sites to follow up the water chemistry and carbon dynamics over timescales of days to months. Primary production and algal community composition will be monitored to determine any fertilization effect from the release of silica or iron from olivine.

The accumulation of olivine reaction products with depth in the pore water will provide insight into possible saturation effects on the olivine dissolution rate. The geochemical conditions within the sediment (i.e. the actual conditions at which olivine dissolves) will be quantified in detail through microsensor profiling (O_2, H_2S, pH), high-resolution pore water geochemistry (A_T, DIC, NO_3, NH_4, PO_4, SO_4, DFe, DSi, trace metals) and solid phase analysis (organic C and N, $CaCO_3$).

At regular time intervals, olivine particles will be recovered from the sediment to inspect the grain surfaces for dissolution features and secondary mineral precipitates by means of X-ray computed tomography combined with XRF. The resulting geochemical dataset (pore water depth profiles, fluxes) will be used in geochemical model simulations in order to accurately constrain fluxes and process rates, including organic matter mineralization and olivine dissolution (virtual seafloor environment).

12. Explain your precise claim to ownership of the negative emissions that you are offering. In particular, explain your ownership claim: 1) in cases in which your solution indirectly enables the direct negative emissions technology and 2) when, based on the LCA above, your solution relies on an additional upstream or downstream activity before resulting in negative emissions. Please address the notion of "double counting" if applicable to your project, and how you'll prevent it.

Max 200 words

For this pilot project, Project Vesta will oversee the entire life cycle from the quarry to the beach, minimizing energy expenditure in the life cycle of the mining, milling and transport to maximize net CO2 removal. We will then quantify and monitor the weathering rate of the olivine on the beach. Project Vesta is the direct and sole claimant of all negative emissions from this project and we have full rights to direct the sale for the totality of our emissions to Stripe. As such, there are no questions about incrementality or double-counting of the negative emissions.

Section 6: Potential Risks

This section aims to capture Stripe Purchase Criteria 5: The project is globally responsible, considering possible risks and negative externalities.

13. Describe any risks or externalities, any uncertainties associated with them, and how you plan to mitigate them. Consider economic externalities, regulatory constraints, environmental risk, social and political risk. For example: does your project rely on a banned or regulated chemical/process/product? What's the social attitude towards your project in the region(s) it's deployed, and what's the risk of negative public opinion or regulatory reaction?

Max 300 words

For Project Vesta to scale, we need access to beaches and shelf seas in order to deploy olivine at these sites. All countries with eroding coastlines are familiar with the concept of beach nourishment, where sand is transported from one area and deployed to another.

A key risk to the project's speed is our ability to work with governments to secure permission to deploy. The regulations on this vary by country, and this adds a layer of potential constraints onto the project. As a result, we are working with governments, to ensure that we conduct all deployments within local regulatory frameworks.

From a public opinion standpoint, the project is relatively new and unknown, and therefore there is social/political risk that the public is not accepting of the technique. We are working to ensure a 'YIMBY' attitude exists towards Vesta. There are numerous benefits to local ecosystems and communities so we believe this risk is manageable, but we must be proactive in mitigating it. Local benefits include de-acidifying the ocean (a key co-benefit of the Vesta chemistry), nourishing beaches with more sand (loss of sand due to erosion being a major problem in numerous countries), improved shellfish and fishery yields, and tourism benefits from the green-sand beaches that Vesta creates.

In 2020 we will run experiments to measure the effects of Vesta deployments on local biogeochemistry and marine ecosystem populations and biodiversity. Given that Vesta de-acidifies the ocean and increases silicate concentrations, the hypothesis is that deployments will, in general, be beneficial rather than detrimental to marine ecosystems. However, there is also the risk of unknown and unintended consequences, hence the experiments we plan to run. One such risk is that the introduction of trace amounts of Nickel, which is contained in olivine, into the sea, will cause harm to certain marine species. For various reasons we classify this risk as low, but we wish to highlight it here in the spirit of full transparency.

Heavy Metals such as Nickel:

Renforth and Montserrat show, in an unpublished study (in preparation), that in the waters of a natural olivine bay in Hawaii, no apparent adverse effects on the biological community were observed. Different organism groups (algae, benthic macrofauna, corals) were sampled, where a higher Nickel concentration in the respective tissues was measured, compared to a control location. Although further research is needed, these higher Nickel levels did not seem to directly indicate environmentally damaging effects of the olivine sand on the beach. Further data by Project Vesta advisors, who have published an ecotoxicological risk model for heavy metal ligand binding from the weathering of silicates (such as olivine), suggest that olivine would not release metals at a rate that would have a negative effect on the environment. In addition, they found that most Nickel probably reacts with various other dissolved compounds to precipitate into solid form and thus not be bio-available.

Section 7: Potential to Scale

This section aims to capture Stripe Purchase Criteria 6: The project has the potential to scale to high net-negative volume and low cost (subject to the other criteria).

14. Help us understand how the cost and net-negative volume of your solution will change over time. Note that we aren't looking for perfect estimates. Instead, we're trying to understand what the long-term potential is and what the general cost curve to get there looks like. (Note: by "cost" here we mean the amount Stripe or any other customer would pay for your solution):

	Today	In ~5 years	In ~20 years
Est. Cost per net-negative ton (in $)	$25-$75	$10	$5
Est. Net-negative volume (in tons of CO2)	500 tonnes/yr	At least 1 million tonnes/yr	At least 10 gigatonnes/yr

15. What are the drivers of cost? Which aspects of your costs could come down over the next 5 years, and by how much? Do you think your eventual scale potential is limited by cost or by volume? Why? Refer to any relevant constraints from question #7, like land or materials scarcity, and specify the boundary conditions for which you consider those constraints.

Max 300 words

The main drivers of cost are mining, milling, and transport. All of these processes will benefit in both efficiency and cost as they become electrified and decarbonized. In terms of mining capacity, based on extrapolating from the number of workers per tonne of olivine mined at the world's largest olivine mine, it would only take 1-1.5 million people globally to mine enough olivine for total yearly anthropogenic CO2 emissions offsetting. There is enough olivine available in accessible dunite layers of ophiolites to scale up to more than a trillion tonnes of CO_2 removal, although a large number of additional mines will need to come online to meet demand.

Section 8: Only for projects with significant land usage

See Stripe's Purchase Criteria 2: The project has a net cooling effect on the climate (e.g. carbon negative complete life cycle, albedo impact, etc.) ***This section is only for projects with significant land usage requirements: Forest, Soil, and BECCS/Biochar/Biomass sequestration projects.***

16. Location: Please provide baseline information about the geographic location(s) of your project; and link shapefile(s) of project area(s).

Max 100 words

Project Vesta has no meaningful albedo impact. The only land use is on the beach itself, where we deploy a layer of olivine sand 1-2cm thick over the beach. We do not consider this to be a significant land usage requirement.

17. Land ownership: Please describe the current (and historical as relevant) land ownership and management for the area(s) provided in (16). If your project is not the landowner, describe your relationship to the landowner.

Max 150 words

We are working with the government of a Caribbean island nation to use remote beaches. The experimental beach is surrounded by private livestock grazing land and is not easily accessible by the public. We are working with the nearest village to receive informed consent from them as we go forward and plan to make the project have an economic stimulus to their area. Including hiring locals to secure the beach and help us with last-mile olivine transport.

18. Land use: For forest projects, please provide details on forest composition as well as forest age and basal crop area/density. For soil projects, please provide details on land use and crop type (if agricultural), soil organic carbon baselines, and regenerative methodology. For BECCS, biochar, or wooden building materials projects, please provide details on biomass crop type and methodology as applicable.

Max 500 words

N/A

19. Net effect on climate: Please discuss the non-CO_2 impacts of your project that may not be covered in your LCA, such as your impact on albedo.

Max 150 words

No other direct effects on climate, but Project Vesta de-acidifies the ocean locally at deployment sites. This has significant potential to improve the health of local marine ecosystems. Coral reefs, for example, are dying as a result of ocean acidification, and since they provide the physical substrate for numerous other organisms, improvements in their health could have numerous benefits. In addition, shellfish and fishery yields have been decreasing as a result of ocean acidification, so Project Vesta has the potential to offset these losses.

Section 9: Other

20. What one thing would allow you to supercharge your project's progress? This could be anything (offtakes/guaranteed annual demand, policy, press, etc.).
Max 100 words

Having our process classified as beach nourishment and accepted for use by the government for both resilience of the coastlines against erosion as well as CDR.

21. (Optional) Is there anything else we should know about your project?
Max 500 words

More information and additional sources at ProjectVesta.org

Section 10: Submission details

*This section **will not** be made public.*

22. Please insert below the name and title of the person submitting this application on behalf of your company (or, if you are submitting this application on your own behalf, your own details). By submitting this application, you confirm that you have read and accept the Project Overview (available HERE), as well as the further conditions set out below. As a reminder, all submitted applications will be made public upon Stripe's announcement. *Once you've read and completed this section, submit your application by March 20th by clicking the blue "Share" button in the upper right, and share the document with **nets-review-2020@stripe.com**.*

Name of company or person submitting this application

[redacted]

Name and title of person submitting this application (may be same as above)

[redacted]

Date on which application is submitted

[redacted]

We intend to make the selection process as informal as possible. However, we do expect that (a) the content of your application is, to the best of your knowledge, complete and correct; (b) you do not include any content in your application that breaches any third party's rights, or discloses any third party's confidential information; (c) you understand that we will publicly publish your application, in full, at the conclusion of the selection process. You also understand that Stripe is not obliged to explain how it decided to fund the projects that are ultimately funded, and - although extremely unlikely - it is possible that Stripe may decide to not proceed, or only partially proceed, with the negative emissions purchase project. Finally, if you are selected as a recipient for funding, Stripe will not be under any obligation to provide you with funding until such time as you and Stripe sign a formal written agreement containing the funding commitment.