

- PV general comments
 - We thank the Committee of the Project Vesta Review Board (PVRB) for the review and for the detailed comments and questions. We have two general comments in addition to our responses below.
 - We note that several months elapsed between Project Vesta submitting the document for review and receiving the comments. During this interval, Project Vesta further developed its approach and how we communicate various aspects of it. We have noted areas in which we either already have or plan to submit updated documents to the PVRB.
 - Several of the questions pertain to details of sampling and analysis protocols which were not included in the permit application. As noted in our responses, we will submit our full sampling and analysis protocols to the PVRB for formal review.

- They still talk about the “trillion tons of CO₂”. This sounds dodgy and does not build trust. Obviously, they are unrealistic and will not remove a trillion tons.
 - PV: this was intended as a very long-term vision, which could indeed occur over the course of centuries so we disagree that this is obviously unrealistic. However, we agree with the feedback that it sounds unrealistic and we removed this from our messaging some time ago.
- You occasionally see that they have a very positive attitude towards this approach, so there is potential of human bias in their assessment. Everyone must be careful.
 - PV: We agree that it is critical to avoid bias and any possible perception of it. We acknowledge that as an organization we have a mission to help address the damaging effects of climate change. Part of our motivation comes from optimism that this could work, and this sometimes comes through in our writing. Project Vesta’s responsibility is to accelerate the science of this field to enable scientists and policy-makers to assess the risks and benefits of CEW and make evidence-based decisions about its suitability as a negative emissions technology. Irrespective of the outcomes of this research, these results will be critical to add to the dearth of general knowledge on ocean alkalinity enhancements and its effects on carbon cycling and the biosphere. We believe the possible perception of bias resulting from our mission obligates us to set a high bar for rigor and dispassionate research. This comes partly from our voluntary submission to review by the PVRB.
- I have seen that PV engages with US colleagues on Hawaii to study olivine beaches as natural analogues. This should be considered as a major building block for evidence in phase 1 and inform the decision whether or not to move on to phase 2.
 - PV: We agree. We see studying Papakolea as an important factor for moving forward with phase 2 at our first pilot site.
- They have no research on the hydrographics in there. How does the signal dilute along the beaches? How fast would currents drift the perturbed water away? How fast is air-sea CO₂ exchange? This is relevant.
 - PV: We agree that these factors are important. We have conducted preliminary experiments with floating tracers which suggest the residence time of water in the pilot bays is on the order of a few hours to a day in the 0 to ~3 m-deep bays. We are currently developing a three dimensional, submetric resolution model of each bay in order to spatially simulate current patterns. Along with dye tracers deployed in situ, this will allow us to predict the residence time of

water within the bays and the fate of the olivine dissolution byproducts. Rates of air-sea exchange are harder to predict, as they depend on both the $p\text{CO}_2$ difference between the air and the sea and on the gas transfer velocity. Given the rough waves characterizing the Northern shore of [location redacted], and the relatively high wind speeds encountered on the island (Elliott et al., 2001), it is likely that the average gas transfer velocities in the bays are going to range between 10 and 50 cm per hour (Ho et al., 2006).

- The methods are described very briefly, hard to say if they are good enough. But they have good people on board so I trust they will do it well.
- They talk a lot about capacity building as some major benefit of the study for [location redacted]. However, they do not describe in the text how this is achieved.
 - Due to the diverse types of research required to study olivine dissolution in situ, Project Vesta is working with a range of international and local researchers who are best suited for particular types of studies. For example, many geochemical and genetic assays involve sending samples collected in the [location redacted] to labs in the USA due to specific equipment or personnel needs. Other analyses like ecological surveys, ecotoxicology, social sciences, etc., will be conducted locally with research organizations. For example, we are collaborating with a local coral lab, Fundemar, to help fund and support more personnel and infrastructure needed for ecotoxicology experiments. This project also involves collaboration with a former Venezuelan professor who advises Fundemar on their experimental designs. They will also be helping us find a student to help run these studies locally. We are working with this group to design our coral experiments. Our research facilities, lab, sediment mesocosms, and office space will be open resources for local collaborators and any additional studies they may wish to conduct at the pilot beaches.
- They should disclose why they do it in [location redacted], not in the US. It always raises eye-brows when a first world company does the environmental assessment in a poorer country.
 - PV: The choice of location was based primarily on the identification of a particularly suitable pair of similar bays to be used as test and control sites. PV is committed to conducting its research under both the standards of in-country permitting authorities and those of the PVRB.
 - In addition, social science literature on negative emission technologies calls for greater research into perception, attitudes, and social licensing in developing countries. PV is engaged in a social science program to publish a comparative study of Caribbean vs US attitudes towards Ocean CDR.
 - The team is working to establish formal collaboration agreements in the form of a Steering Committee with the National Council for Climate Change and Clean Development, Minister of the Environment and Natural Resources, Academy of Sciences, [location redacted] Geological Society, the Environmental Network of [location redacted] Universities, and the National Authority for Marine Affairs. This Steering Committee will be reviewing and approving every stage of our research program.

Specific comments:

“Project Vesta’s vision is to help reverse climate change by turning a trillion tons of CO₂ into rock. Coastal Enhanced Weathering (CEW) can do this by harnessing the power of wave energy”

- This is unproven speculation. No one knows that the method can remove even a million tons. They should not sell it as if they already knew.
 - PV: The intent was not to sell it as if we already have proven it. This was presented as a ‘vision’, which by its nature is speculative. However, we accept that the phrasing could be interpreted as demonstrating more certainty than we have, and we have since adjusted our communication to reflect this.

“...And dramatically increases the rate of weathering.”

- Unproven. Or if proven, then this needs a reference to show us.
 - PV: We agree. It has been established that grinding down olivine grains to small sizes dramatically accelerates weathering rates (Monsterrat et al., 2017). Anecdotal evidence from unpublished research implies that it is possible to increase weathering rates with mechanical activation, but the influence of wave energy on weathering rate must still be investigated. This is a research focus for Project Vesta.

“CEW de-acidifies the water”

- raises pH. Seawater is alkaline
 - PV: We agree. ‘De-acidifies’ is a reference to ocean acidification. By adding alkalinity to the ocean, CEW has the potential to counteract ocean acidification.

“ If we can do this, we can deliver to the planet a carbon dioxide removal method that captures 50% of annual human emissions every year, using an area consisting of 1% of global shelf seas (0.0016% of the total area of the oceans).”

- Unsound speculation. They promise something they are unable to meet. Why is everyone exaggerating so much in the CDR world?
 - PV: We agree that this was speculative, though it was based on calculations in unpublished research by Schuiling & de Boer. We have already altered our communication about scale to bring this into line with the lower end of the literature consensus on maximum scale.

“The whole project aims to study the effects of olivine in a field setting.”

- effects on what?
 - PV: This sentence could be more completely written as “The whole project aims to study the effects of olivine-sand addition on coastal chemistry, geomorphology, and ecology in a field setting.”

“Phase 1: Baseline environmental assessment”

- Splitting the process in two phases makes a good impression. I think this is a good way of doing it as they create awareness during the first phase and engage in a public discussion before commencing the more controversial part.

“That coastal ocean water is always well-mixed by wind and waves causes it to be in chemical equilibrium with the atmosphere.”

- This may be true for beaches (although even there I am not sure) but not for the coastal ocean in general. In reality it is possible that CO₂ deficient seawater subducts and remains isolated from the atmosphere before equilibration takes place. PV should map out how they

attempt to monitor atmospheric CO₂ influx into the oceans. They probably can't do this easily, which is why they need a strategy here (see also major comment).

MH: Yes, important point. Even at the annual timescale this isn't the case, but at shorter timescales even less so due to e.g. algal blooms.

- PV: In general, in the shallow coastal ocean, equilibration will occur on fast timescales (weeks to years, Mongin et al., 2021), relative to the residence time of water in the coastal ocean (Lacroix, 2021). The Caribbean bays that will host the proposed Phase 2 tests should be able to equilibrate quickly, although probably not entirely, with the atmosphere (see our reply above). PV will quantify the residence time of water in the bays with dye-tracer experiments. Additionally, to quantify the flux of atmospheric CO₂ into the water, we will calculate the pCO₂ of seawater by measuring DIC, pH, and alkalinity (two of the three are needed; we will measure all three), directly measure the pCO₂ of the atmosphere, as well as measure the gas transfer velocity through SF₆ tracer experiments. We will also measure wind speed as an additional constraint on gas transfer velocity. In certain coastal areas, subduction of water to the deep ocean is expected to occur. Project Vesta will conduct oceanographic modeling to understand and predict the sea current spatial patterns at each deployment site. That water containing alkalinity released by olivine dissolution remains in contact with the atmosphere as long as possible is a criterion for deployment site selection.

“Coastal environments are ideal for ESW, because...”

□ again, if they are so ideal then why doing this research. Who are you trying to convince here?

MH: Indeed, I can think of reasons why other environments are better suited. Aren't you trying to say that among marine ecosystems, coastal environments may be best suited?

- PV: ‘Ideal’ may not have been the best word choice. The intent was to communicate that in our opinion based on the available research to date, the coastal environment shows the most promise for carbon removal through enhanced weathering. This is why we are applying our research to this environment rather than any other one.

Insights can be gained by analogy with other impacts (e.g. selective Si fertilization of coastal ecosystems by glacial meltwater)

□ This is an excellent point. Vesta should perhaps look very thoroughly into natural analogues for coastal ESW. I know they do this on Hawaii which makes a lot of sense and should be implemented in this proposal and on the way towards the eventual field application in phase 2

- PV: We agree. We have initiated a study in Hawaii in collaboration with Dr. John Burns (University of Hawaii, Hilo) to study the natural analogue at Papakolea.

“Phase 2”

□ I suggest they have a Phase 1b where they present the results from the natural analogue beaches on Hawaii to justify continuation with phase 2 (or the stop after phase 1b).

- PV: We see the natural analogue study as a gating factor for phase 2, so we agree.

“The p in pH stands for the negative natural logarithm, or -ln, so the lower the pH, ...”

□ The p and the H in pH stand for "potentia hydrogenii" and it is log₁₀, not natural logarithm.

JG: agree

- PV: We agree, thank you for noticing our error.

“[pH+]”

without the +

- PV: We agree.

“The exact rate and efficiency of olivine dissolution in the field (in nature) is one of the most important points to be investigated in this pilot project”

Agreed but this is Phase 2, right?

- PV: Yes this is Phase 2.

“Model simulations have shown that the bio-available portion of trace metals, released from dissolving olivine, do not approach environmentally dangerous levels, but this is yet to be confirmed within an experimental framework”

Vesta shall clearly state the "official" threshold concentrations.

MH: And, in addition, explain bio-available and why this is relevant in the context of these threshold conditions.

- We define bioavailable as available for organisms to incorporate into their tissues. Some trace metals (e.g., iron and nickel) are critical micronutrients for microbes and plants at specific concentrations. While we are still investigating this, we believe trace metals may experience limited bioavailability and biomagnification (transfer up to higher trophic levels) (Pourahmad et al. 2005) due to numerous adsorption substrates in the sediment, formation of oxides, complexation with marine ligands, etc. For example, sediments are typically considered a chromium (Cr) sink in marine environments due to the various adsorption substrates (e.g., organic matter, oxides, carbonates, etc.) (Pourahmad et al. 2005). Evidence also suggests Cr is not biomagnified to higher trophic levels. Data on nickel (Ni) bioavailability in marine sediments and seawater is lacking. Much of Ni bioavailability is determined by the types, concentrations, and binding affinities to particular aquatic ligands and substrates that ultimately reduce bioavailability (Binet et al. 2017). Furthermore, Ni reactions with dissolved organic matter (DOM) are difficult to quantify but do occur, thereby limiting bioavailability. Of the few data available, Ni sensitivity varied across taxonomic groups, and the literature generally calls for more research, especially in tropical marine ecosystems (Gissi et al. 2016). In oxic marine environments, iron is generally insoluble as iron oxides which, in principle, renders it biologically unavailable. Some microbes have developed biotic ligands to complex iron, thus making it bioavailable for growth. We are conducting extensive ecotoxicology experiments with collaborators to test this. We are also running experiments with particular microbial taxa as well as with natural microbial communities to investigate the concentrations of olivine dissolution products that may support or hinder biotic growth. Additionally, many coastal areas that tend to have higher concentrations of micronutrients (metals) and macronutrients (nitrate, phosphate) generally do not limit the growth of natural microbial populations. If these populations are not limited by potential nutrients derived from olivine dissolution (e.g., iron), then we do not expect to see significant increases in primary productivity. Hence, for every site, we will characterize the nutrient availability for microbial growth as well as the additional fluxes of potential nutrients from olivine dissolution. In addition, we will provide any threshold concentrations established by regulation or regulatory authorities.

“The research project has the following objective”

The objectives are reasonable.

“Phase 3 will not proceed unless toxicology studies verify that olivine does not pose a significant threat to local marine life”

□ I am confused now. What is phase 3? Isn't phase 2 the field application of olivine? Field applications should not proceed should the previous ecotoxicology lab studies ring alarm bells

MH: I agree, this is confusing.

- PV: This is a typo, it should have read 'Phase 2'. Field experiments will not proceed if the ecotoxicology studies show concern at the predicted concentrations in the field. The PVRB will review the data and comment before the decision is made whether or not to proceed with Phase 2.

“Measurements”

□ given that pH is a critical parameter I would urge them to take samples for spectrophotometric pH analysis, following Dickson et al.'s best practice guide.

- PV: Agree. We detail that we will be using a spectrophotometer on Page 10. We will follow Dickson et al. (2007)

“Completing the proposed research will produce many types of benefits at all scales, from the communities around the proposed study beaches to the planet as a whole.”

□ By stating that Vesta makes the impression as if they already know the outcome of the study. This makes me wonder if there is bias in their approach.

MH: I fully agree.

- PV: This was poorly phrased. We acknowledge that as an organization we have a mission to help address the damaging effects of climate change. What we mean is that general research into the science of olivine weathering as well as public perception will benefit the broader efforts by the global scientific community in characterizing strategies for CEW and understanding their safety and effectiveness. Project Vesta's responsibility is to accelerate the science of this field to enable scientists and policy-makers to assess the risks and benefits of CEW and make evidence-based decisions about its suitability as a negative emissions technology. Irrespective of the outcomes of this research, these results will be critical to add to the dearth of general knowledge on ocean alkalinity enhancements and its effects on carbon cycling and the biosphere. On the contrary, we believe the possible perception of bias resulting from our mission obligates us to set a high bar for rigor and dispassionate research. This comes partly from our voluntary submission to review by the PVRB.

“All ecological assessments and raw data from this study will be made publicly available”

□ This is good and builds trust.

MH: Can you add how? Through your own website? Dedicated data portal?

- PV: Our aim is to publish these data in peer-reviewed journals which requires data to be publically available for replicability. We will determine what platform or platforms may be best to host these data. This is partially due to the nature of the data. For example, if we study microbial community composition changes in response to olivine dissolution through methods like DNA sequencing, those datasets are typically very large and must be housed in a database like NCBI's Short Read Archive for easy access by the scientific community. However, other analyses will produce much smaller datasets that can be more easily hosted in a smaller data portal.

“The proposed research will build significant scientific community in the [location redacted], with scientist collaborators from around the world coming to Puerto Plata to analyse the data we collect from this study”

□ While possible, it is not explained in the proposal how this capacity building should work. Furthermore, Vesta should disclose why the experiment is done in the [location redacted] and not on US soils.

- PV: Due to the diverse types of research required to study olivine dissolution in situ, Project Vesta is working with a range of international and local researchers who are best suited for particular types of studies. For example, many geochemical and genetic assays involve sending samples collected in the DR to labs in the USA due to specific equipment or personnel needs. Other analyses like ecological surveys, ecotoxicology, social sciences, etc., will be conducted locally with research organizations. For example, we are collaborating with a local coral lab, Fundemar, to help fund and support more personnel and infrastructure needed for ecotoxicology experiments. This project also involves collaboration with a former professor who advises Fundemar on their experimental designs. They will also be helping us find a student to help run these studies locally. We are working with this group to design our coral experiments. Our research facilities, lab, sediment mesocosms, and office space will be open resources for local collaborators and any additional studies they may wish to conduct at the pilot beaches.

“More job opportunities for scientists and students from the [location redacted] to work directly on climate change research”

□ This is good but how are locals involved. This has not been detailed here.

- PV: Project Vesta has hired a Community Engagement manager and Coordinator to the local team. These two individuals are co-developing our social science framework and outreach program.
- Project Vesta is actively looking for a motivated individual with ecological surveying experience or strong willingness to learn to assist in surveying dives. Ultimately, ecological surveying will need to continue for many years so we would like to train a team locally to continue this essential research.
- We are also in contact with the [location redacted] Geological Society to bring awareness to the abundance of olivine already present within the [location redacted].

Mathilde Hagens' comments:

“Coastal Enhanced Weathering (CEW) refers to a natural geochemical process.. “

□ Reads like a *contradictio in terminis* (enhanced vs natural) - I suggest to rephrase to "CEW refers to the acceleration of a natural geochemical process"

- PV: We agree, thank you for noting this.

“in the real world at a variety of scales”

□ Various spatial scales or temporal scales or both?

- PV: Both spatial and temporal.

“from a variety of perspectives”

□ But all from the natural sciences, isn't? I suggest to specify this.

- PV: from the natural and social sciences

“There are currently no proven methods for doing so”

□ There are proven methods to remove CO₂, but not at this scale. I would specify this.

- PV: ‘doing so’ refers to ‘remove billions of tons of carbon dioxide (CO₂) from the atmosphere’ so we think the statement was accurate as written, but we will adjust this in future documents to avoid any doubt as to the meaning.

“There is an incalculably large benefit”

□ Not the biggest fan of using 'incalculably'

- PV: We understand the concern but stand by the statement. It was not intended as hyperbole, rather to be taken literally: calculating the referenced benefit to any reasonable degree of accuracy would not be possible.

Page 2

“It is possible to accelerate the Earth’s natural carbon removal method of rock weathering, by extracting the volcanic mineral olivine, grinding it into sand, and transporting it to coastlines”

□ The natural processes of weathering involves many more minerals/rocks than just olivine. I think this needs an explanation why you focus on olivine for this work.

- PV: True. We will add to future documents the reason for focusing on olivine rather than other minerals.

“In the earth’s natural long-term carbonate-silicate cycle, rain falling on exposed volcanic rock causes it to weather, which removes CO₂ from the atmosphere as bicarbonate dissolved in water (Hangx et al., 2009; Hartmann et al., 2013; Montserrat et al., 2017).”

□ These are all EW studies, better to cite studies looking at the actual natural weathering process.

- PV: Good point, thank you.

“When they die, they form ocean sediment, ultimately becoming limestone.”

□ Only a small fraction of them - the rest dissolves before settling.

- PV: We agree. We used this explanation to clarify the link to the long-term carbon cycle and accept the accuracy of your comment.

“This could cost as little as \$200B per year, which is a small fraction of the cost of other permanent methods of CDR.”

□ How do you define 'permanent'? (e.g. beyond the human timescale) Good to be specific.

- PV: Good point. We use a commonly-used definition of >1,000 years

“the natural weathering process of volcanic silicates by placing these on beaches”

□ Here you talk about 'volcanic silicates', of which olivine is an example. So (referring to my earlier comment) make sure to specify why you focus on olivine even though weathering includes more minerals/rocks.

- PV: Agreed. We will specify in future documentation the reason for focusing on olivine.

Page 3

“and also because of the almost immediate effect it will have on atmospheric CO₂”

□ 'almost immediate' if I read this I think about timescales of less than seconds. Better to just specify the timescale.

- PV: Agreed. The timescale of CO₂ removal once olivine is dissolved is effectively the timescale of air-sea CO₂ equilibration which may vary seasonally but is generally short (weeks to years) in well-mixed coastal environments. In the context of climate solutions this is ‘almost immediate’, but we agree that specificity on the temporal scale is helpful here. This compares with the residence time of water in coastal environments of a few years (Lacroix, GBC 2021).

“However, until now, a field trial has not been undertaken to assess ESW in a natural coastal setting, and the effects need to be investigated.”

□ The effects on what?

- The whole project aims to study the effects of olivine-sand addition on coastal chemistry, geomorphology, and ecology in a field setting.”

Page 4

“Olivine dissolution will cause chemical effects in the aqueous medium in which the weathering takes place”

□ Chemical changes that will have an effect on biology - that is the focus of your study.

- PV: We agree.

The bicarbonate may dissociate further into carbonate and another proton.

□ Depending on pH

- PV: We agree.

Page 5

“see point (1)), but the silicon fertilization effect and stimulation of the biological carbon pump may cause additive effects.”

□ I would argue to include not only a possible increase of the biological pump, but also a possible shift in algal composition and impacts on the marine food web as part of this research topic.

- PV: We agree. We are conducting a range of experiments to study potential microbial community composition changes in response to olivine dissolution. Laboratory studies with keystone taxa (eg diatoms/cyanobacteria) are being designed to understand physiological changes and potential uptake of olivine dissolution products. Mesocosm studies examining natural communities will seek to understand how community composition shifts. Finally, tag DNA sequencing will be used to track community changes both in the sediment and overlying water column.

“Develop a high-resolution baseline of environmental conditions at both beaches”

□ Beaches have not yet been introduced - I suggest to rephrase to give a little bit more information on the beaches.

- PV: Good point. We will note this feedback for future documentation.

“Determine the natural variation of each parameter that is part of the regular sampling protocol”

□ At which spatial/temporal intervals?

- PV: Since the permit was submitted we have updated our sampling protocols. These will be provided to the Review Board as part of the experimental review process.

Page 6

“The experimental setup of the field pilot study for coastal enhanced weathering of olivine has been designed to exceed best practices for impact assessment and monitoring.”

□ What is the aim of 'exceeding best practices' instead of following them? To design new best practices?

- PV: The aim is to conduct robust, peer-reviewed studies that go beyond what may be required for similar types of beach modification projects like coastal nourishment. So We plan to exceed existing best practices because of the novelty of ESW.

“The experiment will follow the Before-After-Control-Impact protocol of monitoring,”

□ But this is only in Phase 2, isn't it? It is a bit confusing to describe it here.

JG: the BACI approach is highly suitable for this purpose

- PV: We agree. The BACI approach refers to both phases of the study, not just Phase 2.

“Monitoring of all parameters will be conducted weekly for a minimum of three months prior to the treatment in order to establish the environmental conditions present at the control and treatment sites”

□ Three months is too short to account for any seasonal effect - plus, what determines when the study is concluded?

- PV: We agree. In order to fully account for seasonal effects we would need a ~5 year baseline period. Given that this is the first field trial of many and that we have a BACI design, we believe we can meet the scientific objectives of the study in 12 months or less before placing olivine (subject to clearing other gating factors such as ecotoxicology and Papakolea studies). After this, the decision to proceed with Phase 2 will be based on establishing a meaningful baseline sampling dataset and will be made in close consultation with the Review Board, local Steering Committee, and other stakeholders including the local community.

Page 8

“Playa Viejo Oscar; lat/long 19.9011037,-70.8645385 [control beach] Playa Cala Madiana; lat/long 19.9011037,-70.8645385 [treatment beach]”

□ But no treatments yet in phase 1 - make sure to clarify this. Also, from the maps I can't see which beach is which - the screenshot is too small to be readable.

- PV: Confirming no treatments in Phase 1. The eastern beach is the test beach and the western beach is the control beach.

Page 10

“Sampling will be conducted in a 3x4 grid array according to the following diagram”

- Can you add distances / a scale bar to the map? Also, please include metric units for sampling in addition to coke can and cups.
- PV: Yes, we will provide this to the Review Board as part of our updated sampling protocols.

“Each 36 sample set will be collected daily for 7 days, then weekly for 3 months, then monthly for 3 months.”

- Earlier you only talked about weekly sampling for 3 months.
- PV: Since we submitted this document we have revised our sampling schedule and will provide this to the Review Board.

Page 11 / 12 / 13 (generic comment for all described methods)

Can you please add references to the protocols you will be following? It is difficult to assess the methodology without knowing which protocols you will be using and e.g. how samples will be stored. Also, do the bottle numbers refer to the order of sampling of the bottles?

- PV: We will provide full details of the protocols to the Review Board.

Page 14

“Project timeline”

- I can't see the timeline for some reason.
- PV: We will provide this to the Review Board.

Page 15

“This study will produce a comprehensive assessment of natural resources from geologic, chemical, physical and biological perspectives for the two proposed beaches”

'Natural resources' is not the term I would use here - maybe write "geologic, chemical, physical and biological parameters/characteristics" instead

- PV: Noted, thank you.

“Potential for an increase in tourism to the area to visit the olivine beaches and research facilities”

- How are you envisioning this?
- PV: In the case that the local community expresses a need or interest in increased tourism to the area for economic gains, we believe our work could attract this through ecotourism in partnership with the Ministries of Tourism and Environment. We believe that members of the public are interested in research studying potential mitigation to climate change. The combination of this and the attractive natural setting provide for the possibility of visitors. We envisage low-impact ecotourism in which visitors tour the study sites and research facilities under the guidance of the local community, bringing much-needed dollars to the region.

Page 2

It is possible to accelerate the Earth's natural carbon removal method of rock weathering, by extracting the volcanic mineral olivine, grinding it into sand, and transporting it to coastlines.

- I would not speak of rock but about minerals and it may also help when the reaction product is dissolved HCO_3 as long as it does not return to CO_2
- Not exclusively volcanic. It is a mineral and found in highest amounts in ultramafic rocks or silt
- PV: We agree.

This could cost as little as \$200B per year, which is a small fraction of the cost of other permanent methods of CDR

- a ref is necessary here. Different figures are around
- PV: We have since done further work on cost estimates and we will provide these to the Review Board.

one of the most promising approaches to climate change mitigation is enhancing the natural weathering process of volcanic silicates

- remove volcanic. Note that dunite is a plutonic rock
- PV: Olivine is present in both volcanic and plutonic rocks, however, we agree that ESW does not inherently require 'volcanic' silicates and we will remove this term in future documents.

Page 3

Enhanced silicate weathering (ESW) uses sand particle-sized silicate minerals

- as before: or silt
- PV: In our opinion, silt-sized particles should generally be avoided for ESW in coastal settings. For example, they are often explicitly prohibited or severely limited in beach nourishment because of the impact they can have on water (e.g turbidity) and sediment (e.g. porosity) quality. For these reasons, we are focusing on sand-sized particles.

The continuous movement of waves and currents will cause mechanical impacts between particles that break them down to smaller particle sizes.

- also important is the abrasive effect on secondary coatings on the olivine grains. These coatings will slow down the weathering rate but are assumed to come loose from the primary grains
- PV: We agree.

Page 4

one molecule olivine dissolving consuming nominally four protons.

- if no secondary carbonates become formed
- PV: We agree.

Following the air-water equilibrium, increasing atmospheric CO_2 concentration ($p\text{CO}_2$) will lead to increased $p\text{CO}_2$

- note this should be capital P which refers to pressure. regular p refers to -log as explained below in the text itself. Check throughout
- PV: We agree.

Page 5

do not approach environmentally dangerous levels,

- it all depends; this statement is too blunt
- PV: We agree this statement is too blunt as written. Please see the answer above on bioavailability which explores the concept in more depth.

Page 6

Baseline Sampling

- I would prefer more time and not daily when one could sample 7 times. Gives better idea of weather variability, etc.
- PV: We have updated our planned sampling schedule and will share it with the Review Board.

a model organism study program

- rather unspecifically described. Some ideas what kind of tox test would be fine
- PV: We have since provided our ecotoxicology study plans to the Review Board and will provide a further update on these.

Page 7

Dissolved Abundant Metals

- meaning of abundant not clear to me. I assume the main cations?
- PV: Yes, we are referring to the major cations.

Sediment Porewater

- sulphate could be nice when one suspects SO₄ reduction (and H₂S as well)
- PV: Agree. Although we are material-limited with respect to porewaters we will investigate adding this to our analyses. We will use the Cline method to investigate H₂S production in the porewaters.

Page 10

9 sites per beach

- this is not a 3x4 grid
- PV: Correct, that was an error. The grid will be 3x3 for sediment samples and 3x4 for water samples. Details of this will be provided to the Review Board in the updated sampling protocols referenced elsewhere in this document.

Page 11

Sediment – three 10cm sediment cores per location, all analytes derived from shared source material

- same; the method of extraction is crucial
- PV: We agree. We are putting significant effort into testing extraction methods to ensure we isolate samples from the appropriate depths.

Page 12

Sediment Porewater - three sediment cores per location, all analytes derived from shared source material.

- once more: what are the methods? total Po₄, ortho-PO₄, NO₃, NO₂, NH₄, Kjeldahl-N?
- PV: We will provide the protocols to the Review Board.

3. The results from Phase 1 research will determine the appropriate scales of observation in space and time for detecting the effects of olivine on the environment
 - this is still a question as we do not yet know the weathering rate
 - PV: This sentence was referring to the idea that the results of Phase 1 will establish the spatial and temporal heterogeneity of the bay's geochemistry, which, in turn, will inform what spatial and temporal scale must be monitored following olivine deployment, in order to resolve the signature of olivine dissolution on bay geochemistry. The weathering rate will be constrained through the study.

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