International Ocean Discovery Program Expedition 390/393 Scientific Prospectus Addendum

South Atlantic Transect

A multidisciplinary IODP investigation along a crustal flow line across the western flank of the southern Mid-Atlantic Ridge

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Abstract

The South Atlantic Transect (SAT) is a multidisciplinary scientific ocean drilling project that will recover complete sedimentary sections and the upper ~250 m of the underlying oceanic crust along a slow/intermediate spreading rate Mid-Atlantic Ridge crustal flow line at ~31°S. These cores were originally scheduled to be collected during International Ocean Discovery Program (IODP) Expeditions 390 and 393 in October–December 2020 and April–June 2021, respectively. In 2020 and 2021, the global COVID-19 pandemic resulted in the postponement of several IODP expeditions, including Expeditions 390 and 393, chiefly because science parties were unable to travel to the R/V *JOIDES Resolution*. In response, the ship was used to conduct preparatory work for the postponed expeditions that did not require a science party aboard but could be carried out by the ship's crew and a team of technicians from the *JOIDES Resolution* Science Operator. Two of these expeditions (390C and 395E) were in service of the SAT drilling project, to reduce the operational risks and expedite basement drilling during the rescheduled Expeditions 390 and 393. Expeditions 390C and 395E visited five of the six primary SAT sites and successfully cored a single advanced piston corer/extended core barrel hole penetrating the entire sediment section and <10 m into the underlying basalt before installing a reentry system in a second hole at each site visited. Given these accomplishments, the operations plans for the rescheduled Expeditions 390 and 393 have been revised.

1. SAT engineering Expeditions 390C and 395E

The South Atlantic Transect (SAT) expeditions will target six primary sites on 7, 15, 31, 49, and 61 Ma ocean crust, which will fill critical gaps in our sampling of intact in situ ocean crust with regards to crustal age, spreading rate, and sediment thickness. International Ocean Discovery Program (IODP) engineering Expeditions 390C and 395E were implemented in response to the global COVID-19 pandemic and occupied sites proposed for the postponed Expeditions 390 and 393, South Atlantic Transect 1 and 2. The overall objective of the SAT engineering expeditions was to lay the foundations for Expeditions 390 and 393 by coring one hole through sediment to basement at each primary SAT site with the advanced piston corer/extended core barrel (APC/XCB) system for gas safety monitoring and by installing a reentry system with casing through the sediment to between ~5 m above basement and <5 m into basement in a second hole.

Capturing the sediment/basement contact along the SAT is critical to documenting chemical exchange, alteration, and microbiological processes across this interface. The operational plans for the engineering expeditions therefore included using the XCB system with a polycrystalline diamond compact cutting shoe to core the lowermost sediments and advance up to 10 m into the underlying igneous rocks in each APC/XCB hole to determine the thickness of the sediment cover and recover this critical boundary for future sampling and study. The assumption was that this system would provide cleaner recovery of the interface by causing only minimal disturbance and yielding high recovery compared to rotary core barrel (RCB) coring systems. All RCB drilling was deferred to Expeditions 390 and 393.

During Expedition 390C, which sailed in October–November 2020 (Estes et al., 2021), the sediment section was cored at four of the SAT sites (U1556–U1559). The reentry systems were to be installed using the Dril-Quip running tool. However, there were difficulties installing casing into basement with this system. The extra time taken for troubleshooting meant that reentry installations could not be completed at all sites, and a second expedition was planned. IODP Expedition 395P (February–April 2021) was given the go-ahead by the *JOIDES Resolution* Facility Board to complete the reentry system installations without a science party. Unfortunately, Expedition 395P did not leave port in Cape Town, South Africa, because of COVID-19 cases among the staff and crew in the port call hotel and on the ship. Its operations were deferred to Expedition 395E (April–June 2021), which completed most of the SAT preparatory work that Expedition 390C did not have time to complete (Williams et al., 2021).

1.1. Expedition 390C operations

Expedition 390C started in Kristiansand, Norway, and ended in Cape Town, South Africa, after 31 days of on-site operations (Estes et al., 2021). Single APC/XCB sediment holes were cored at four of the primary SAT sites (U1556, U1557, U1558, and U1559; proposed Sites SATL-53B, SATL-56A, SATL-43A and SATL-13A, respectively), coring <10 m into the underlying basaltic lavas (Table **T1**), and reentry systems with casing were installed at three of these sites (Figure **F1**). The contact with basalt was slightly deeper than estimated at all of the sites, likely because of a slight underestimation of the in situ seismic velocities. At Site U1556, basalt was encountered significantly deeper than estimated (at 278 meters below seafloor [mbsf] instead of the estimated 180 mbsf); a shallow reflection at 6.9 s two-way traveltime that marked a change in seismic character from high-frequency to low-frequency reflectivity was misinterpreted to be basement. A deeper reflector has now been reinterpreted to be basement. Given the thick sediment layer at Site U1556 and consequent reinterpretation of seismic data for this area, the estimated basement contact

Table T1. South Atlantic Transect site details. * = see Risks and contingency. Latitude and longitude are for holes with reentry systems, where installed. APC = advanced piston corer, XCB = extended core barrel.

Site	Proposed site	Primary/ Alternate	Expedition		Latitude	Longitude	Water depth (m)	Age (Ma)	Half spreading rate (mm/y)	Estimated sediment thickness (m)
			Completed operations	Planned operations						
Drilled/Planned sites										
U1559	SATL-13A	Primary	390C	390	30°15.6336′S	15°2.0941′W	3055.7	6.6	17.0	50
U1560	SATL-25A	Primary	395E	393	30°24.2057′S	16°55.3702′W	3723.7	15.2	25.5	104
	SATL-33B	Primary		393	30°42.6174′S	20°26.0340′W	4193.0	30.6	24.0	138
U1558	SATL-43A	Primary	390C	393	30°53.7814′S	24°50.4822′W	4334.4	49.2	19.5	148
U1556	SATL-53B	Primary	390C	390	30°56.5244′S	26°41.9472′W	5006.4	61.2	13.5	180
U1557	SATL-56A	Alternate	390C, 395E	390	30°56.4651′S	26°37.7892′W	5012.3	61.2	13.5	510
U1561	SATL-55A	Alternate	395E	*	30°43.2902′S	26°41.7162′W	4909.5	61.2	13.5	126
Alternate sites										
	SATL-11B	Alternate		*	30°13.3398′S	15°2.2902′W	3057	6.6	17.0	104
	SATL-12A	Alternate		*	30°6.2256′S	15°2.8992′W	3373	6.6	17.0	96
	SATL-23A	Alternate		*	30°23.7210′S	16°52.7844′W	3819	15.2	25.5	162
	SATL-24A	Alternate		*	30°24.0126′S	16°55.8318′W	3676	15.2	25.5	94
	SATL-31A	Alternate		*	30°45.8436′S	20°25.9530′W	4188	30.6	24.0	183
	SATL-35A	Alternate		*	30°37.9506′S	20°26.1516′W	4157	30.6	24.0	93
	SATL-41A	Alternate		*	30°0.1992′S	24°49.1478′W	4408	49.2	19.5	203
	SATL-44A	Alternate		*	30°53.8218′S	24°52.1706′W	4283	49.2	19.5	176
	SATL-54A	Primary		*	30°56.5452′S	26°43.3128′W	4991	61.2	13.5	639

Table T1 (continued).

Site	Proposed site	Primary/ Alternate	APC/XCB cored hole					Installed reentry system		
			Hole	Expedition	Observed sediment thickness (m)	Average sediment accumulation rate (m/My)	Total penetration (m)	Hole	Expedition	Casing shoe depth (mbsf)
Drilled/Planned sites										
U1559	SATL-13A	Primary	A	390C	64.0	9.70	66.2	B	390C	55.3
U1560	SATL-25A	Primary	A	395E	120.0	7.89	122.5	B	395E	122.0
	SATL-33B	Primary				4.51				
U1558	SATL-43A	Primary	A	390C	158.9	3.23	163.9	D	390C	146.1
U1556	SATL-53B	Primary	A	390C	278.0	4.54	283.8	B	390C	284.2
U1557	SATL-56A	Alternate	B	390C	564.0	9.22	574.0	D	390C/395E	571.6
U1561	SATL-55A	Alternate	A	395E	46.0	0.75	49.0			
Alternate sites										
	SATL-11B	Alternate								
	SATL-12A	Alternate								
	SATL-23A	Alternate								
	SATL-24A	Alternate								
	SATL-31A	Alternate								
	SATL-35A	Alternate								
	SATL-41A	Alternate								
	SATL-44A	Alternate								
	SATL-54A	Primary								

depth of 639 mbsf at proposed Site SATL-54A would have required us to exceed the drill string weight limit, which is equivalent to a maximum deployable casing string length of ~600 m in that water depth (~5 km). We therefore replaced Site SATL-54A with alternate Site SATL-56A, where the basement contact was estimated to be shallower, at 510 mbsf.

Two failed attempts at drilling in casing and a reentry system into hard rock at Site U1558 revealed that the Dril-Quip reentry cones and running tools are incompatible with use in hard rock. The release mechanism does not work when the casing string weight cannot be fully removed from the running tool, which can happen when the base of casing is in basement. Therefore, at Sites U1558 and U1559, casing was installed to ~10 m above basement. Site U1557 has a thick sediment cover (564 m) requiring two casing strings to reach basement; a reentry system with the first (16 inch) casing string was installed to 60 mbsf in Hole U1557D during Expedition 390C.

1.2. Expedition 395E operations

Expedition 395E started in Cape Town, South Africa, and ended in Reykjavík, Iceland, after 20 days of on-site operations (Williams et al., 2021). The aim during Expedition 395E was to complete the SAT reentry system installations, installing casing up to 5 m into basement at each site to make a more stable hole for basement coring because the uppermost basement can be unstable. However, this was not always possible because of local seafloor and basement surface topography (Figure **F1**; Table **T1**). A single APC/XCB hole was cored at Site U1560 (proposed Site SATL-25A), coring <3 m into the underlying basaltic lavas, and a reentry system was installed using the hydraulic release tool (HRT). The next site of Expedition 395E was originally planned to be proposed Site SATL-33B, the middle site of the SAT on 30.6 Ma crust. However, because of a 4 day delay in leaving port, operations at SATL-33B were deferred until Expedition 390 or 393 to ensure casing operations could be completed in Hole U1557D, where a reentry system with 60 m of 16 inch casing was installed during Expedition 390C. This site was technically more challenging because the heavy weight of ~5 km of pipe and 573 m of 10¾ inch casing meant that the installation could only take place under calm conditions. Expedition 395E took advantage of a predicted

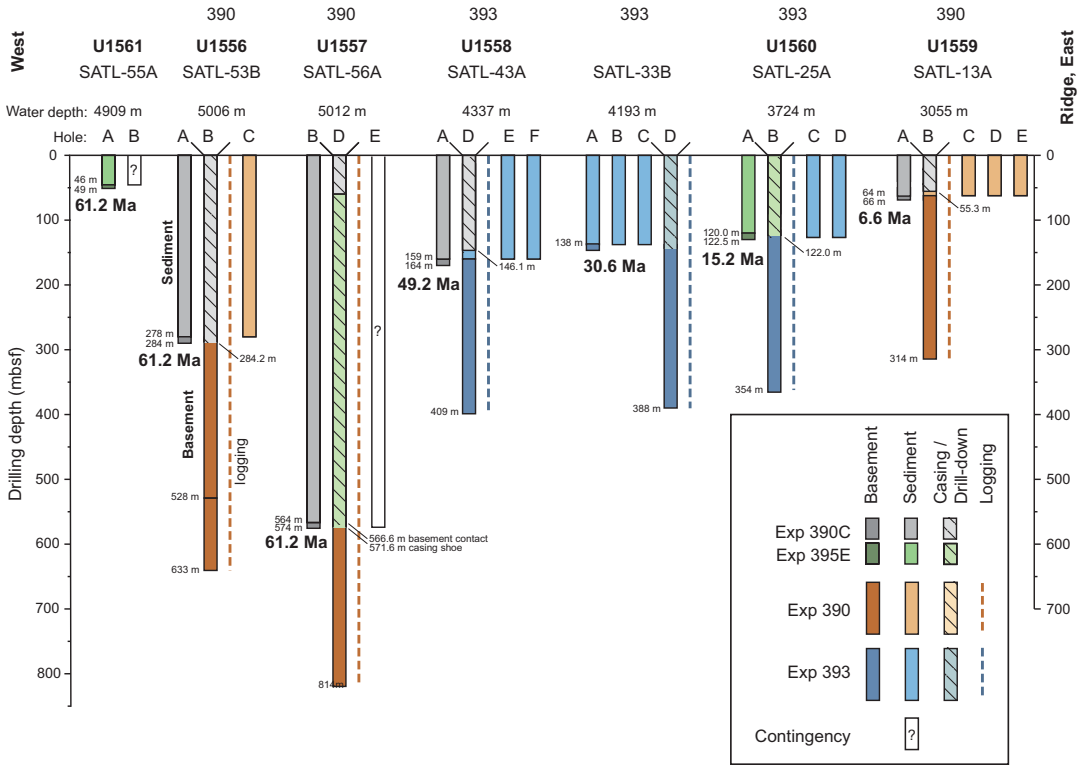

Figure F1. Accomplished operations (Expeditions 390C and 395E) and remaining work to be completed during Expeditions 390 and 393 at South Atlantic Transect sites.

weather window of calm seas at Site U1557 to complete the casing installation in Hole U1557D using the Dril-Quip running tool, which was required for compatibility with the existing reentry hardware installed during Expedition 390C. Following installation of a reentry system in Hole U1556B using the HRT, there was insufficient time to return to proposed Site SATL-33B. Instead, a single APC/XCB hole was cored at nearby Site U1561 (proposed Site SATL-55A) to 47 mbsf, where the recovered cores comprised red clay and carbonate ooze overlying 3 m of basalt.

1.3. Expedition 390C and 395E scientific results

The APC/XCB cores recovered during Expeditions 390C and 395E will be considered part of Expeditions 390 and 393 and will be described in detail by the Expedition 390 and 393 shipboard science parties. To ensure the ephemeral properties of these cores were determined, a range of analyses were conducted during Expeditions 390C and 395E. These included in situ formation temperature measurements made with the advanced piston corer temperature tool, physical properties, linescan images, X-ray images on the whole-round (WR) and split-core tracks, and paleomagnetic measurements on the archive halves. In addition, one sample per core was collected for headspace gas analysis and one to two WR samples per core were collected for chemical analysis of interstitial water. Core catcher samples were also collected for distribution to the Expedition 390 and 393 micropaleontologists to develop preliminary biostratigraphic age models ahead of Expeditions 390 and 393. A summary of the shipboard data is provided in the Expedition 390C and 395E *Preliminary Reports* (Estes et al., 2021; Williams et al., 2021). The geochemical data will guide chemical and microbiological sampling during Expeditions 390 and 393.

2. Revised Expedition 390 and 393 operations plans

Expedition 390 was originally scheduled to start in Rio de Janeiro, Brazil, on 5 October 2020 and end in Cape Town, South Africa, on 5 December, and Expedition 393 was scheduled to start in Cape Town on 6 April 2021 and end in Rio de Janeiro on 6 June. Both expeditions will now start and end in Cape Town; Expedition 390 is now scheduled to start on 7 April 2022 and end on 7 June, and Expedition 393 is now scheduled to start on 7 June and end on 7 August. The original operations plans for Expeditions 390 and 393 (Coggon et al., 2020) were designed to achieve the following objectives at each of the six sites along the SAT:

1. Recover a complete sediment section,
2. Install a drill-in reentry cone and casing to near the sediment/basalt boundary,
3. Core to ~250 meters subbasement (msb), and
4. Collect wireline geophysical logging data through the basement sections.

The operations plans for the rescheduled Expeditions 390 and 393 have been revised to account for the following:

- The operations already completed along the SAT.
- The installation of the "thick sediment" reentry system on 61 Ma crust at proposed Site SATL-56A instead of proposed Site SATL-54A.
- The thicker than expected sediment at primary SAT sites (Table **T1**).
- The change in port calls, with both expeditions no longer required to transit the entire SAT.

The successful installation of five of the six planned reentry systems along the SAT prior to Expeditions 390 and 393 significantly decreases the operational risk of the SAT expeditions and should allow time for additional operations, provided the remaining operations of the original plan go well. The time savings due to operations already completed are partially offset by the need to sail to and from Cape Town, which adds additional transit time to both expeditions, and extra time that will be required to core the thicker than expected sediments. The revised operations plans for Expeditions 390 and 393 are summarized in Tables **T2** and **T3**, and the combined SAT expedition operations are illustrated in Figure **F1**. The time required to complete these operations was estimated assuming (1) APC/XCB recovery of sediments at ~10 m/h, which is consistent with previous drilling in similar rock types (e.g., Shipboard Scientific Party, 2004), and (2) decreasing rates of basalt penetration during RCB operations of 4.5 m/h in the uppermost 50 m, 3 m/h through the

subsequent 100 m, and 2 m/h thereafter, based on previous drilling results in basaltic basement. The time allocated for wireline logging includes deployment of the triple combo tool, the Ultrasonic Borehole Imager (UBI), and at least two passes of the Formation MicroScanner at each site as per the original Expedition 390 and 393 operations plans (Coggon et al., 2020).

2.1. Revised sediment coring strategy

The original Expedition 390 and 393 operations plans (Coggon et al., 2020) included coring three APC/XCB sediment holes at each crustal age along the SAT to allow compilation of complete paleoceanographic records across core breaks using stratigraphic correlation and provide sufficient material for WR microbiological and pore water sampling. This will now be achieved as a result of the combined operations of Expeditions 390C, 395E, 390, and 393 (Figure **F1**). A fourth APC/XCB sediment hole will also be drilled at Site U1559 (located on 7 Ma crust), where minimal extra operational time is required, given the thin sediment cover (<70 m), to provide additional material for microbiological sampling. Sites U1556 and U1557 are located in the same localized sedimentary basin on 61 Ma crust where significant basement topography results in variable sediment thickness (~278 and 564 m thick, respectively). As per our original plan, the sediment section on 61 Ma crust will comprise two APC/XCB holes to basement at Site U1556 and one APC/XCB hole to basement at Site U1557. The latter was completed during Expedition 390C, during which microbiological sampling was not possible.

2.2. Revised basement coring strategy

The original operations plan included deployment of two RCB bits at each primary SAT site, following installation of a reentry system. Given the expected basement penetration rates and 40–

Table T2. Operations plan and time estimates, Expedition 390. mbrf = meters below rig floor. APC = advanced piston corer, RCB = rotary core barrel, XCB = extended core barrel, FMS = Formation MicroScanner, UBI = Ultrasonic Borehole Imager. DP = dynamic positioning.

Site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations description	Transit (days)	Drilling/ coring (days)	Logging (days)
Cape Town			Begin expedition 4.8 Port call days			
			Transit ~2276 nmi to U1556 (SATL-53B) @ 11.0 kt	8.6		
U1556 (SATL-53B)	30°56.5244'S	5017.5	Hole B - RCB to 633 mbsf - Log with triple combo, FMS-sonic, and UBI		12.4	1.6
	26°41.9472'W	(APC_Calc)	Hole C - APC/XCB to 283 mbsf (offset 20 m south from Hole U1556B)		3.4	
			(location is for Hole U1556B reentry system)			
			Subtotal days on site: 17.4			
			DP transit ~3.6 nmi to U1557 (SATL-56A) @ 1.0 kt	0.1		
U1557 (SATL-56A)	30°56.4651'S	5023.4	Hole D - RCB to 814 mbsf - Log with triple combo, FMS-sonic, and UBI		8.6	1.8
	26°37.7892'W	(APC_Calc)	(location is for Hole U1557D reentry system)			
			Subtotal days on site: 10.4			
			Transit ~600 nmi to U1559 (SATL-13A) @ 11.0 kt	2.3		
U1559 (SATL-13A)	30°15.6336'S	3067.0	Hole C - APC/XCB to 65 mbsf (offset 20 m east from Hole U1559B)		1.0	
	15°2.0941'W	(APC_Calc)	Hole D - APC/XCB to 65 mbsf (offset 20 m south from Hole U1559C)		0.4	
			Hole E - APC/XCB to 65 mbsf (offset 20 m west from Hole U1559D)		0.7	
			Hole B - RCB to 310 mbsf - Log with triple combo, FMS-sonic, and UBI		7.0	1.3
			(location is for Hole U1557B reentry system)			
			Subtotal days on site: 10.4			
			Transit ~1709 nmi to Cape Town @ 10.5 kt	6.8		
Cape Town			End expedition	17.8	33.5	4.7

Port call days:	5.0	Total operating days:	56.0
Subtotal days on site:	38.2	Total expedition days:	61.0

Table T3. Operations plan and time estimates, Expedition 393. mbsl = meters below sea level. APC = advanced piston corer, XCB = extended core barrel, RCB = rotary core barrel, FMS = Formation MicroScanner, UBI = Ultrasonic Borehole Imager. EPSP = Environmental Protection and Safety Panel.

Site	Location (latitude, longitude)	Seafloor depth (mbsl)	Operations description	Transit (days)	Drilling/ coring (days)	Logging (days)
Cape Town			Begin expedition 5.0 Port call days			
			Transit ~1801 nmi to U1560 (SATL-25A) @ 11.0 kt	6.8		
U1560 (SATL-25A)	30°24.2057'S	3723.7	Hole C - APC/XCB to 125 mbsf	0	1.3	0.0
EPSP	16°55.3702'W	(APC calc)	Hole D - APC/XCB to 125 mbsf	0	1.2	0.0
to 354 mbsf			Hole B - RCB to 354 mbsf - Log with triple combo, FMS-sonic, and UBI	0	7.4	1.5
			(location is for Hole U1560B reentry system)			
			Subtotal days on site: 11.3			
			Transit ~410 nmi to U1558 (SATL-43A) @ 11.0 kt	1.6		
U1558 (SATL-43A)	30°53.7814'S	4334.4	Hole E - APC/XCB to 164 mbsf	0	1.6	0.0
EPSP	24°50.4822'W	(APC calc)	Hole F - APC/XCB to 164 mbsf	0	1.6	0.0
to 398 mbsf			Hole D - RCB to 409 mbsf - Log with triple combo, FMS-sonic, and UBI	0	7.8	1.7
			(location is for Hole U1558D reentry system)			
			Subtotal days on site: 12.6			
			Transit ~227 nmi to SATL-33B @ 11.0 kt	0.9		
SATL-33B	30°42.6174'S	4204	Hole A - APC to 138 mbsf	0	1.7	0.0
EPSP	20°26.0340'W		Hole B - APC to 138 mbsf	0	0.9	0.0
to 388 mbsf			Hole C - APC to 138 mbsf	0	1.3	0.0
			Hole D - Reentry system to 133 mbsf	0	1.8	0.0
			Hole D - RCB to 388 mbsf - Log with triple combo, FMS-sonic, and UBI	0	7.7	1.7
			Subtotal days on site: 14.9			
			Transit ~1970 nmi to Cape Town @ 10.5 kt	7.8		
Cape Town			End expedition	17.0	34.0	4.9

Port call days:	5.0	Total operating days:	55.9
Subtotal days on site:	38.9	Total expedition days:	60.9

50 h rotation on each RCB bit, the expected basement penetration is 250 m at each site. The revised operations plan (Figure **F1**; Tables **T1**, **T2**) includes additional time for basement coring at the highest priority site (U1556), which has experienced the full history of ridge flank hydrothermal exchange across the SAT, with a new target depth of 350 msb. Expedition 393 will install a reentry system at proposed Site SATL-33B using the HRT prior to RCB coring. Expedition 393 will visit this site last to provide the flexibility to use a free-fall reentry cone to save operational time if required. To ensure that all basement holes are left clean for any future operations, the second RCB bit will be dropped on the seafloor at each site rather than in the hole prior to wireline logging operations.

3. Risks and contingency

Our priority is to achieve the greatest possible basement penetration at each site following the recovery of complete sedimentary sections and sampling of the sediment–basement transition. This will require flexibility in our operational plans to counter any unexpected eventualities. The greatest risk to the SAT project is the loss of time because of weather or as a result of personal, medical, or mechanical incidents. Other risks to the completion of the planned operations include operational problems, for example difficulties installing casing into basement or stuck pipe, and lower than predicted penetration rates, which would affect the penetration that could be achieved in the allotted time. The multiexpedition nature of the SAT project allows for additional operational flexibility compared to normal single expedition IODP projects. This gives the option to adapt the operational plan of Expedition 393 in response to the operations completed during

Expedition 390. The highest priority sites (U1556 and U1559) at either end of the SAT are deliberately scheduled during Expedition 390 to give an opportunity to revisit these sites during Expedition 393 if key operational objectives have not been met. The Co-Chief Scientists will therefore work with the Operations Superintendent to review Expedition 390 and revise the operations plan for Expedition 393 as needed. To optimize the drilling operations that can be achieved across both Expeditions 390 and 393, the remaining operations at Site U1557 are also planned for Expedition 390 to (1) minimize the transit time required during Expedition 393 and (2) provide operational flexibility because some operations could be conducted at Sites U1556 and U1557 in succession using a single pipe trip given their proximity. This represents a change from the original operations plans, in which basement drilling at Sites U1556 and U1557 was split between the two expeditions.

In the event of a loss of operational time, the operations plans (Tables **T2**, **T3**) will have to be adapted. The nature of any changes would depend on the circumstances, amount of time lost, and operations already completed. Possible changes we could make to the operations plans include the following:

- Reduce the number of APC/XCB holes at selected sites,
- Reduce the number of RCB bits used at selected sites,
- Reduce the basement penetration depth at selected sites,
- Deploy a free-fall rather than drill-in reentry cone at proposed Site SATL-33B,
- Adjust the frequency of additional operations (e.g., core orientation measurements),
- Adjust the wireline logging schedule, and
- Reallocate the basement drilling time from the lower priority site (U1560).

In the event that we have additional time available, for example through failure of a hole, that time would be reallocated. Additional operations could include the following:

- Additional APC/XCB coring of sediments at Site U1557, which was cored during Expedition 390C and therefore was not previously sampled for microbiological investigations;
- Additional APC/XCB coring of sediments at secondary Site U1561, which was cored during Expedition 395E and therefore was not sampled for microbiological investigations;
- Deeper RCB basement coring at priority sites;
- APC coring of sediments at alternate sites with thicker (higher resolution) sediment sections (Table **T1**); and
- Revisiting Expedition 390 sites during Expedition 393 to measure basement temperatures.

In addition to the above contingency plans, we will further increase our operational flexibility as follows:

- We will carry sufficient spare hardware, including an extra reentry cone system, additional casing, and free-fall reentry cones; and
- The half-length APC coring system will be available.

4. Description of 390C/395E cores

The APC and XCB cores collected during engineering Expeditions 390C and 395E will be described during Expeditions 390 and 393, with Expedition 390 shipboard scientists responsible for describing all cores from sites revisited during Expedition 390 and Expedition 393 shipboard scientists responsible for all remaining cores.

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