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The Biology of Deep-Sea Vents and Seeps: *Alvin's* Magical Mystery Tour

by

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The Biology of Deep-Sea Vents and Seeps

Alvin's Magical Mystery Tour

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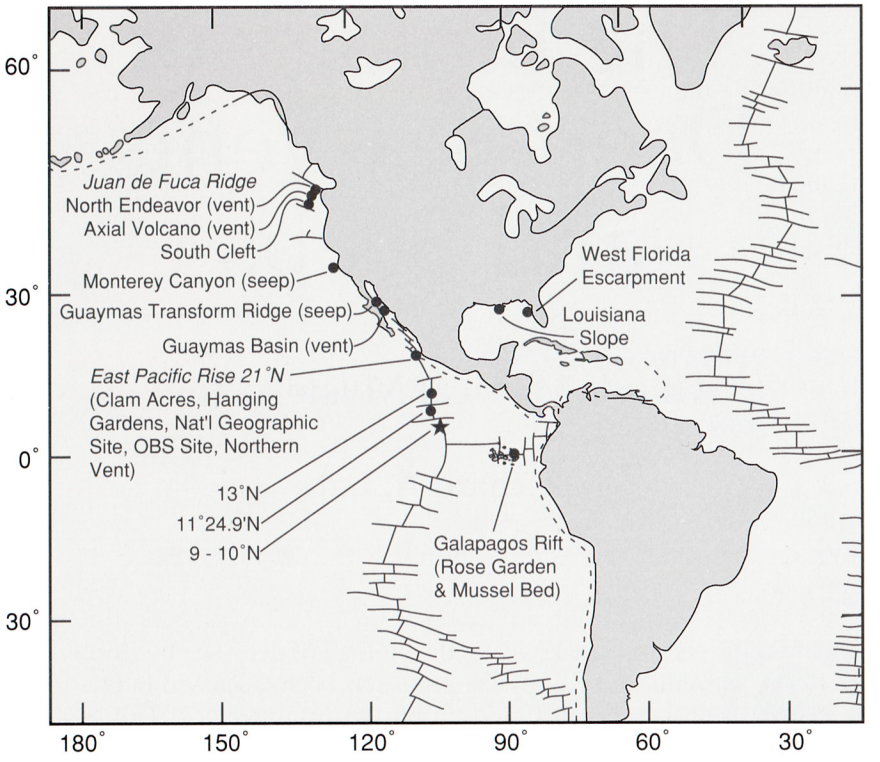
Over the past 12 years, the biology of deep-sea hydrothermal vents and cold-water seeps has been discussed in *Oceanus* several times. (For example, see Summer 1979, Fall 1984, and Winter 1988/89.) Here I provide an overview of a number of recent DSV *Alvin* expeditions to the East Pacific and the Gulf of Mexico that have expanded our knowledge of biological communities present at deep-sea vents and seeps in these oceanic regions. From May 1990 through August 1991, we (Bob Vrijenhoek and I, both of Rutgers University) organized several biological expeditions, collectively known as the "Magical Mystery Tour," as part of an ongoing National Science Foundation-funded project to study the genetics and dispersal mechanisms of organisms inhabiting vent environments. During this "tour," *Alvin* visited 14 deep-sea hydrothermal vent fields and 4 cold-water-seep areas. In April 1991 an additional expedition, known as the ADVENTURE (Alvin Diving in the VENTURE hydrothermal fields) cruise, led by Rachel Haymon (University of California at Santa Barbara) and Dan Fornari (Lamont-Doherty Geological Observatory), visited an extensive series of hydrothermal vents located between 9° and 10°N along the East Pacific Rise (EPR). A number of observations, ranging from faunal changes that had occurred at sites previously visited by *Alvin* to the nature of communities encountered at new areas, are summarized below.

An oceanographic expedition without a proper T-shirt is just another cruise—this is the logo for the Magical Mystery Tour T-shirt.

Hydrothermal Vents

Galapagos Rift

Rose Garden. Scientists diving in *Alvin* visited the Rose Garden hydrothermal vent site (named for the abundance of red-plumed tube worms found there) in 1979, 1985, and 1988. Bob Hessler (Scripps Institution of Oceanography), who dove extensively at this site during each of these



Deep-sea hydrothermal vents and cold seeps visited by Alvin *between March 1990 and August 1991 on the Magical Mystery Tour are plotted here.*

previous visits, returned to the site in May 1990. From Bob's perspective, while significant faunal changes had occurred between 1979 and 1985 (notably a decrease in tube worm abundance, an increased dominance of mussels and clams, a crash in anemone and serpulid populations, and increased numbers of galatheid crabs and whelks), the community structure had not changed significantly between 1985 and 1990.

Mussel Bed. During May 1990 the vent area known as Mussel Bed was also revisited. In 1979 this area was inhabited by an extensive population of large, living mussels (*Bathymodiolus thermophilus*), numerous specimens of the giant clam *Calyptogena magnifica* (as well as significant numbers of empty clam shells), brachyuran crabs (*Bythograea thermydron*), galatheid crabs (*Munidopsis* sp.), whelks (*Phymorhynchus* sp.), pink bythitid vent fish very close to vent openings, two or three small tube worms (*Riftia pachyptila*) in the narrow vent openings, and

The Rose Garden vent site along the Galapagos Rift as it appeared in 1979 (left) and 1985 (right).

R. R. Hessler

L. W. Fritz

many species of limpets. The 1990 visit found a vent environment that had changed remarkably little since 1979; mussels remained the dominant megafaunal constituent, live and dead clams were present in significant numbers, bythitid vent fish were still present around vent openings, and two or three small tube worms were seen in narrow vent openings. In contrast to the marked changes that had occurred at Rose Garden since 1979, time appeared to have stood remarkably still at the Mussel Bed site over the same 12-year period.

9° to 10°N Along the East Pacific Rise

Rachel Haymon, Dan Fornari, and their co-workers have recently described a series of established and newly formed hydrothermal vents between 9°16′ and 9°54′N along the East Pacific Rise. Sampled vent organisms include:

- three species of tube worms (*Riftia pachyptila, Tevnia* sp., *Oasisia* sp.),
- the clam *Calyptogena magnifica*,
- the mussel *Bathymodiolus thermophilus* (with an associated commensal polychaete living in the mantle cavity of over 75 percent of the collected specimens),
- nine species of limpets (*Eulepetopsis vitrea, Lepetodrilus cristatus, L. elevatus, L. ovalis, L. pustulosus, Neolepetopsis densata, Peltospira delicata, P. operculata,* and *Sutilizona theca*),
- six coiled archaeogastropods (*Bathymargarites symplector, Cyathermia naticoides, Melanodrymia* n.sp., and three unidentified species),
- the mesogastropod *Provanna*sp.,
- one unidentified turrid gastropod,
- one or possibly two species of galatheid crabs within the genus *Munidopsis*,
- the brachyuran crabs *Bythograea thermydron* and *Cyanograea praedator* (and possibly a third new undescribed brachyuran species),
- at least two species of barnacles (one stalked),
- several species of bacteria occurring in thick mats and thin coatings on basalt and sulfide substrates,
- the polychaete *Amphisamytha galapagensis*,
- the Pompei worm, *Alvinella pompejana*,
- one or possibly two species of tubiculous polychaetes within the genus *Paralvinella*,
- an unidentified serpulid polychaete,
- the commensal polychaete *Branchipolynoe symmytilida* (which inhabits the mantle cavity of the mussel *Bathymodiolus thermophilus*), and
- numerous other unidentified polychaetes, amphipods, brittle stars (ophiuroids), sea stars (asteroids), leptostracans, anemones, sponges, copepods, and benthic foraminifera.

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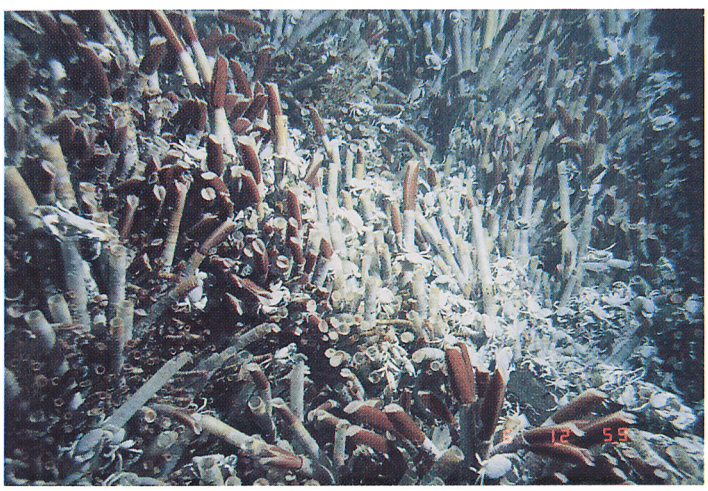
Tube worms, mussels and a zoarcid vent fish at the 9° to 10°N hydrothermal vent fields along the East Pacific Rise.

Zoarcid vent fish were commonly observed, although not sampled, in several vent areas throughout this stretch of the EPR ridge axis.

11° 24.9'N Along the East Pacific Rise

Biologists dove to this site for the first time in June 1990 to find a vent environment characterized by one active black smoker and a few areas with low-temperature venting. Dominant members of the vent megafauna included mussels (*Bathymodiolus thermophilus*), tube worms (*Riftia pachyptila*), galatheid crabs (*Munidopsis* sp.), and brachyuran crabs (*Bythograea thermydron*). Many empty shell valves of the clam *Calyptogena magnifica* were present, but only one living specimen was observed through the submersible's viewport. Other sampled characteristic vent organisms include:



The Genesis hydrothermal vent at 13°N along the East Pacific Rise as it appeared in June 1990.

- four species of limpets within the genus *Lepetodrilus* (*L. cristatus, L. elevatus, L. ovalis,* and *L. pustulosus*),
- the "transparent limpet" *Eulepetopsis vitrea,*
- the slit limpet *Clypeosectus delectus,*
- two coiled archaeogastropods (*Bathymargarites symplector* and *Melanodrymia aurantiaca*),
- the brachyuran crab *Cyanograea praedator,*
- the tube worm *Tevnia* sp.,
- two polychaetes within the genus *Paralvinella* (*P. grasslei* and *P. pandorae*),
- the ampharetid polychaete *Amphisamytha galapagensis,*
- an unidentified serpulid polychaete,
- the commensal polynoid *Branchipolynoe symmytilida,* present in the mantle cavity of over 75 percent of the mussels sampled,
- amphipods, leptostracans, and several unidentified species of polychaetes, which were also abundant in sieve washings and appeared to be associated with clumps of *Riftia* and *Tevnia* tube worms,
- numerous anenomes and brittle stars, which were abundant throughout the hydrothermally active areas, and
- one specimen of an unidentified turrid gastropod.

Numerous specimens of a stalked (goose-necked) barnacle, presently unidentified, were attached to basaltic rocks throughout the vent field. Colonial siphonophores ("dandelions") were observed, but not sampled, in peripheral areas of the vent field, and zoarcid vent fish were relatively common among tube worms attached to the side of the active black smoker.

13°N Along the East Pacific Rise

Three major expeditions in 1982, 1984, and 1987 explored a variety of vent fields in the vicinity of 13°N along the EPR. During this five-year period, marked changes in vent activity and associated faunal composition, ranging from total cessation of vent flow and mass mortality of constituent vent organisms to the "rebirth" of an inactive field, have been reported by Daniel Desbruyeres (IFREMER, Institute Française pour Recherche et Exploitation de la Mar) and his co-workers. In 1990, three vent fields in the 13°N area (Totem, Genesis, and Parigo) were revisited and sampled. Noteworthy observations made during this cruise include:

- a vigorous level of vent activity and lush biological community present at the Genesis site, which was once known as "Pogomort," a vent field that had previously shut down and was named for the large number of associated dead tube worms (the vent tube worms were originally considered members of the phylum Pogonophora but were later placed in the recently erected phylum Vestimentifera),
- an increased dominance in 1990 (in contrast to 1987) of the tube worm Ri*ftia* relative to the tube worm *Tevnia* at the Genesis site;
- newly formed smokers heavily colonized by alvinellid polychaetes in the Genesis hydrothermal field; and
- a few isolated living mussels with no associated vent megafauna at the Parigo vent field, where no heat anomalies were encountered.

21°N Along the East Pacific Rise

A number of hydrothermal vent fields at 21°N along the EPR were visited during major geological and biological expeditions in 1979 (RISE—RIvera Submersible Experiments Expedition), 1981, 1982 (Oasis Expedition), and 1985. In 1990, *Alvin* visited five separate 21°N vent areas, four of which had been previously visited.

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Clam Acres, at 21°N along the East Pacific Rise.

Clam Acres. Nineteen dives were devoted in 1982 to a variety of biological studies, most at an extensive vent field known as Clam Acres. At the beginning of this dive sequence, the area was dominated by large populations of *Calyptogena magnifica* and occasional isolated clumps of the tube worm *Riftia pachyptila*. As a result of the extensive sampling required by the multidisciplinary Oasis program, virtually every clump of tube worms had been "harvested" by the final dive of the series. When this area was revisited in June 1990, biologists were struck by the dramatic rejuvenation of the tube worm population; considerably larger and more numer-

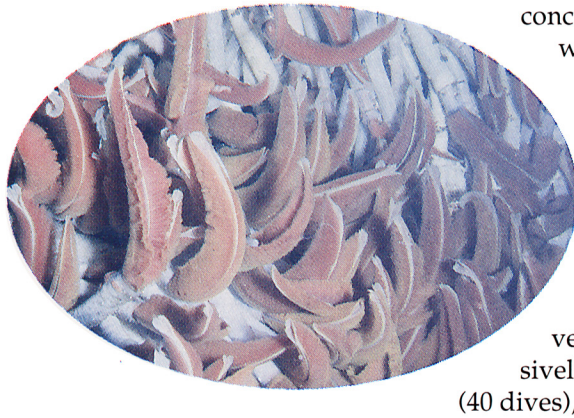
ous *Riftia* clumps were present than had been encountered even during the beginning of the Oasis Expedition, and many of the tube worms within the clumps were more than a meter long. The clam population at this site remained extensive, and associated organisms collected were similar to those sampled in 1982.

Hanging Gardens. Visits in 1979, 1981, and 1985 revealed a lush biological community and one active black smoker at this site. During the return visit in 1990, no dramatic changes in community structure were apparent. The black smoker was still active and the vent field was dominated by two species of tube worms, *Riftia pachyptila* and *Oasisia alvinae*, and numerous clams, crabs, and limpets, all of which had been encountered during previous dives to the site.

National Geographic Smoker (NGS) Site. This vent area, named after a photograph of the site that appeared in the November 1979 issue of *National Geographic* magazine, appeared to have changed little over a 10-year period. Notes in *Alvin* pilots' records from 1981 described dead clam shells, inactive sulfide deposits, a tall, warm vent with white and dark smoke, and a few living clams, tube worms, and crabs. Numerous inactive sulfide deposits were found during the 1990 return visit along with a small (less than 2-meter high), *Alvinella*-covered smoker with temperatures exceeding 300°C. Other biological and geological observations were consistent with the conclusion that little had changed at this vent site since 1979.

OBS (Ocean Bottom Seismometer) Site. In 1981 this site was characterized by three tall chimneys, several dead clam shells, and a few large galatheid crabs (*Munidopsis* sp.), but no other specific vent megafauna. During both the Oasis Expedition in 1982 and the return visit in 1990, at least one of the three chimneys was vigorously active and the only indication of vent-associated organisms was again the presence of dead clam shells and occasional large galatheid crabs.

Northern Vent. Approximately 2 kilometers northeast of Clam Acres, this previously undescribed vent field was encountered by Rich Lutz and Daniel Desbruyeres. While few characteristic vent organisms were observed, tremendous numbers of an attached jellyfishlike organism (within the coelenterate order Stauromedusae) were concentrated around low-temperature vents and were also present in reduced numbers on adjacent basalt surfaces.



These tube worms were attached to a sulfide edifice in Guaymas basin.
Photo by Richard A. Lutz

Guaymas Basin

Unlike each of the other vent sites, the hydrothermal fields of Guaymas Basin are characterized by several hundred meters of soft sediment (with occasional outcropping sulfide edifices) through which vent fluids percolate. This region was extensively studied using *Alvin* in 1982 (10 dives), 1985 (40 dives), and 1988 (24 dives). In June 1990 the Magical Mystery Tour returned to find the region had not under-

gone substantial changes over an eight-year period. Bacterial mats, infaunal vesicomyid clams, and tube worms (*Riftia pachyptila*) on sulfide edifices remained the most conspicuous organisms associated with the vent fields. Empty shells of dead clams were scattered in localized regions throughout the areas of active (or previously active) hydrothermal venting, and black corals with associated terebellid polychaetes were retrieved from box core samples.

Juan de Fuca Ridge

South Cleft Segment. Organisms previously associated with vent fields along this ridge segment were described by Verena Tunnicliffe and A.R. Fontaine (University of Victoria) from photographs and limited samples taken during a 1984 *Alvin* cruise. During August 1991 two of the described vent areas, Vent 1A and 1B, were revisited, and associated vent organisms were sampled or photographed. While many tubes of the tube worm *Ridgeia* sp. were seen at Vent 1A (as they had been during the 1984 cruise) none appeared to contain living organisms and there was no evidence of active hydrothermal venting at the site. Similarly, there was no evidence of living vesicomyid clams at this site, despite the presence of many empty clam shells. Occasional spider crabs (*Macroregonia macrochira*) were the only living vent-associated organisms observed at the site. Approximately 100 meters north of this inactive vent area, a small amount of low-temperature venting was seen percolating through sulfide deposits along the west wall of the axial summit graben. Collections at this site included:

- a few living tube worms (*Ridgeia* sp.),
- two species of limpets, *Lepetodrilus fucensis* and *Clypeosectus curvus*,
- one coiled archaeogastropod species, *Depressigyra globulus*,
- one species of mesogastropod, *Provanna variabilis*,
- one mussel species, *Idasola* sp.,
- palm worms, *Paralvinella palmiformis*, and
- several unidentified polychaetes, a pycnogonid, and one specimen of a living vesicomyid clam.

Several crabs (*Macroregonia* sp.) were seen, though not sampled, and relatively sparse bacterial mats coated the surrounding basalt and sulfide rock surfaces. Vent 1B, which was approximately 300 to 400 meters north, was characterized by numerous, tall sulfide chimneys, several of which were vigorously active. Temperatures as high as 334°C were measured at one of the smoker orifices. Tube worms, other unidentified polychaetes, and sponges were common on the sides of active smokers, and numerous sponges were also seen around the base.

Axial Volcano. The Ashes Vent field within the caldera of Axial Volcano (Axial Seamount) was visited in 1984, 1986, 1987, and 1988. Biological community changes occurring between 1984 and 1988, particularly at an active sulfide mound known as "Mushroom Vent," have been described by Verena Tunnicliffe and are attributed largely to effects of sampling efforts and submersible maneuvering. In August 1991, this vent field was revisited; with the exception of an undescribed limpet species that appeared restricted to previously discharged submersible dive weights, all species sampled had been encountered during previous expeditions

Tube worms, other unidentified polychaetes, and sponges were common on the sides of active smokers.

to this hydrothermally active region. Observations from the 1991 dive revealed a previously unreported substantial quantity of bacteria on basaltic and sulfide surfaces that may have reflected a recent increase in hydrothermal activity or a decrease in the rate of bacterial consumption by a variety of benthic invertebrates in the area.

North Endeavor Segment. A smoker (nicknamed "Godzilla"), the size of a 16-story building (50 meters high), numerous smaller smokers (one affectionately called "Bambi"), and isolated pockets of sediment in low-lying areas along the ridge axis characterized the North Endeavor Segment in August 1991. Sampling efforts on the sides and at the base of Godzilla yielded:

- three species of limpets (Cl*ypeosectus curvus*, *Lepetodrilus fucensis*, and *Temnocinclis euripes*),
- one coiled archaeogastropod species, *Depressigyra globulus*,
- the mesogastropod *Provanna variabilis*,
- two neogastropod species, *Buccinna viridum* and an unidentified cancellarid,
- one aplacophoran, *Helicoradomenia juani*,
- tube worms, *Ridgeia* sp.,
- numerous polychaetes, including three species of *Paralvinella* and the ampharetid *Amphisamytha galapagensis*,
- soft corals,
- hexactinellid sponges,
- anemones,
- a pycnogonid, and
- crabs (*Macrooregonia sp.*) with caprellid amphipods attached to their legs.

Tube worms (upper left), mussels (center) and polychaetes (lower right) at the West Florida Escarpment cold seep.

Many specimens of an unidentified vesicomyid clam were also collected from low-lying, sedimented regions of the axial graben just south of Godzilla.

Cold Seeps

West Florida Escarpment. Alvin visited this cold-water sulfide/methane seep site during geological and biological expeditions in 1984 and 1986. Barbara Hecker (Lamont-Doherty Geological Observatory), the sole biologist to dive at the site in 1984, returned to the seep area in 1990 to find little change in the biological community structure over the six-year period. Sampled or observed organisms included two unidentified mussel species (one of which was collected during both of the previous expeditions; the other was represented in the extensive 1990 samples by only a single individual), vesicomyid clams, the limpet *Paralepetopsis floridensis*, an undescribed coiled trochid gastropod, a turrid gastropod, numerous tube worms (*Escarpia laminata*), ophiuroids, and commensal polychaetes found within the mantle cavities of sampled mussels.

Louisiana Slope. While the first *Alvin* dives to the hydrocarbon seeps of the Louisiana Slope took place in April 1990, these methane-rich areas had previously been studied extensively by Jim Brooks (Texas A&M

University) and co-workers using *Johnson Sea-Link*, *Pisces II*, and *NR-1*. Sampling efforts during the Magical Mystery Tour portion of the 1990 expedition were restricted to collecting two species of vesicomyid clams (*Vesicomya cordata* and *Calyptogena ponderosa*) and several new species of mussels, which are being described and systematically classified as part of ongoing genetic and taxonomic studies.

Guaymas Transform Ridge. Approximately 30 kilometers north of the active hydrothermal fields visited in Guaymas Basin, a transform ridge rises above the seafloor and crests at a depth of approximately 1,600 meters. In 1985, chemist John Edmond (Massachusetts Institute of Technology) and geologist Peter Lonsdale (Scripps Institution of Oceanography) explored the region and found buoyant hydrocarbon plumes and associated assemblages of biological organisms. In March 1991 Luis Soto (Universidad National Autonoma de Mexico) and I returned to the area and sampled several seep-associated organisms from large, depressed "pochmark" regions along the ridge crest. Retrieved specimens included:

- two species of vesicomyid clams,
- numerous specimens of a protobranch bivalve *Nuculana* sp.,
- two limpet species, *Lepetodrilus guaymasensis* and an unidentified species,
- two species of mesogastropods, *Provanna goniata* and *Provanna laevis*,
- several specimens of a heterobranch gastropod *"Melanella" lomana*,
- two unidentified species of tube worms,
- galatheid crabs *Munidopsis* sp.,
- ophiuroids, and
- a variety of miscellaneous polychaetes.

Monterey Canyon. Alvin first visited the Monterey Canyon cold-seep area (located at a depth of approximately 3,400 meters) in October 1988, and returned two years later in September 1990. During both expeditions, the restricted areas of hydrocarbon seepage were characterized by dense populations of large vesicomyid clams with shells more than 20 centimeters long. While few other organisms appeared to be attached to or living among the clams, several empty shells of the protobranch bivalve *Soleyma* sp. were present in adjacent sediments, as were numerous small pogonophorans (phylum Pogonophora, former subphylum Perviata) that were likened by observers within the submersible to "fields of grass."

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Richard A. Lutz is a Professor in the Institute of Marine and Coastal Sciences of Rutgers University. He has been involved in a variety of ecological studies of deep-sea hydrothermal vent communities since the initial discovery of the Galapagos Rift vent fields in 1977. Presently he is Project Coordinator of a large interdisciplinary study of temporal changes in biological community structure at newly formed hydrothermal vents at 9° to 10°N along the East Pacific Rise.

Note: *The author has prepared an informative chart listing the various vent and seep regions and their known resident fauna. If you would like a copy, free of charge, write to* Oceanus *at the address on page 4.*

The author (right) and Howard Sanders (center) prepare to enter Alvin *during an early dive to the Mussel Bed vent along the Galapagos Rift.*