CHARACTERIZATION OF HIGH-ANGLE FAULTS ON THE ISLAND OF SYROS, GREECE

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INTRODUCTION

Exhumation of Aegean blueschist terranes occurred on large-displacement, low-angle normal faults and detachments in a back-arc setting (Okrush and Bröcker, 1990). Ridley (1984) described a network of post-metamorphic listric normal faults on Syros that he related to regional extension, and, using evidence from neighboring islands, bracketed fault activity between the late Miocene to Pleistocene. None of the faults on Syros has been studied in detail, and it remains uncertain whether they are synchronous with or younger than the large-scale normal faults responsible for Aegean blueschist exhumation. Three high-angle faults with well-developed breccia zones are exposed along Syros' western coast (Fig. 1). Field observations and petrographic descriptions of fault matrix material from the breccia zones constrain the ambient conditions during faulting.

METHODS

Fieldwork took place along three high-angle faults with well-developed breccia zones at Cape Diapori, Cape Katakefalos, and the Charasonas Headland (Fig. 1). I described and collected samples from each study site, documented lithologies and contact relationships, measured fault orientation, jointing, bedding planes, foliation, and groove rakes, and conducted a general survey of fault material for clast type, size, roundness, and percent matrix.

Eighteen samples were then cut into polished thin sections. Of those, six were deemed suitable for fluid-inclusion analysis based on petrographic observations of microstructures, mineral deformation, and brecciation. Quartz and calcite crystals in breccia matrix contain fluid inclusions that can be analyzed with a fluid-inclusion stage to provide estimates of the depth and temperature of matrix formation.

FIELD OBSERVATIONS

The high-angle faults at Diapori, Katakefalos, and Charasonas strike NW–SE (Fig. 2) and have well-developed breccia zones that contain similar products, primarily equidimensional angular marble fragments in a cohesive, finely ground carbonate matrix. The clast-rich compositions (10–50%) of the fault rocks fall into textural classifications spanning crush breccia to cataclasite. Crush breccia consists of 0–10% cohesive crystalline matrix and includes fragments >0.5 cm; cataclasite is 50–90% cohesive crystalline matrix with fragments typically <0.1 cm (Sibson, 1977). The faults dip at >60º and have throws no greater than 30 m. All three faults occur at or near the tips of the peninsulas, and may be parts of a larger fault zone that controls the outer western coastline of the island.

Cape Diapori

The fault exposure at Diapori is approximately 200 m long and strikes NW–SE along three en echelon steps, forming a ragged, west-dipping, near-vertical scarp approximately 50 m high. At the north end of the zone, a sharp contact between host marble and fault gouge includes a polished face 50 cm high. Grooves and Riedel shear fractures in the marble footwall

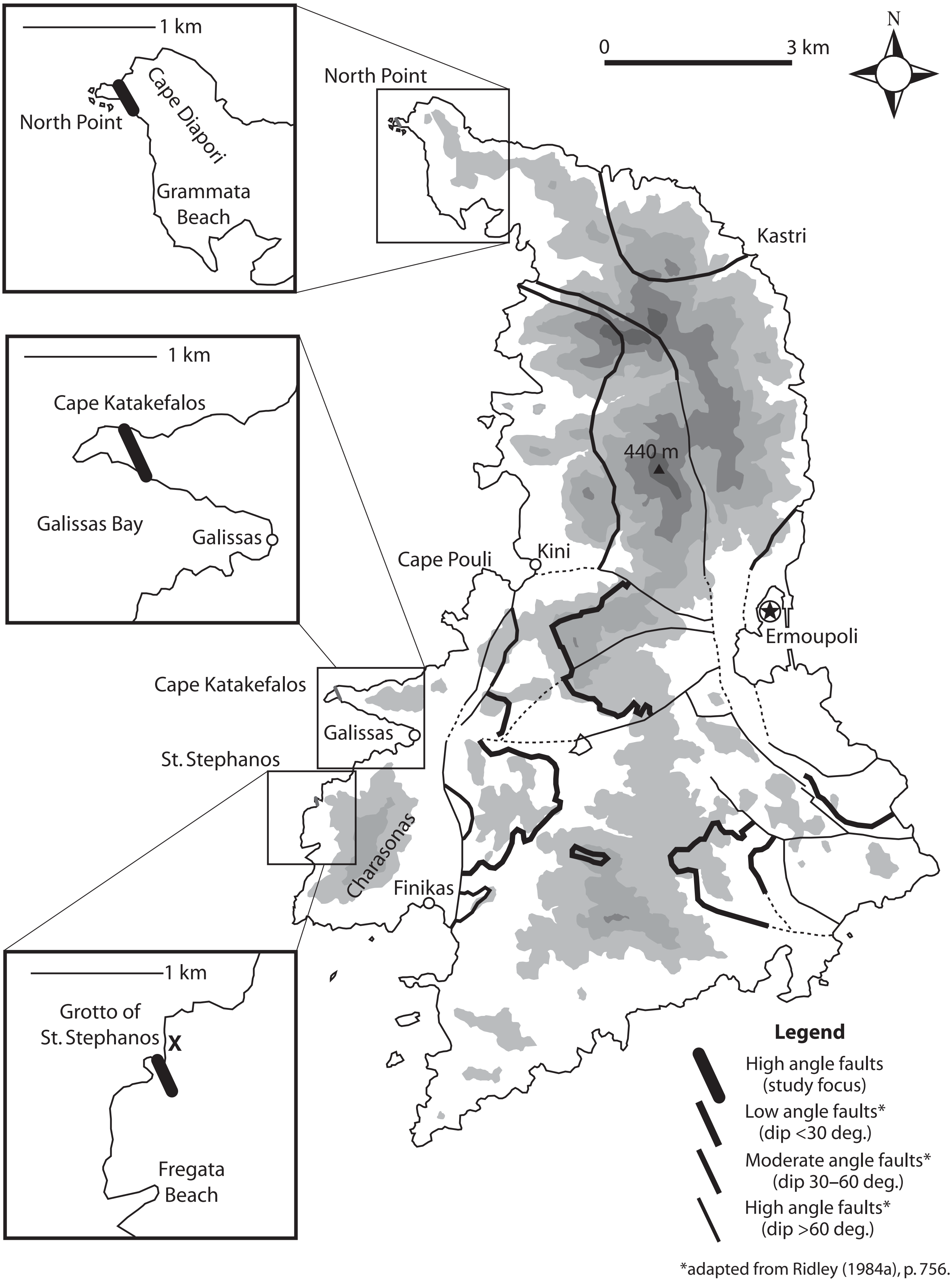

Figure 1: Map of Syros Island. Ridley (1984) documented a network of faults on the island, including several low-angle listric normal structures. Insets show locations of the three study areas of this project—Diapori, Katakefalos, and Charasonas. At all three sites, high-angle faults with well-developed breccia zones strike NW–SE and demonstrate throws no greater than 30 m. The faults occur at or near the tips of the peninsulas, and may be part of a larger fault zone that controls the outer western coastline of the island.

indicate oblique slip of the hanging wall to the south (Fig. 3). The dominant feature of the site, however, is a looming breccia face approximately 70 m long and 15 m high. A tilted block of schist that protrudes from the water immediately southwest of the exposure may be a detached part of the hanging wall.

Cape Katakefalos

A steep, NW–SE-striking normal fault approximately 200 m long cuts the neck of the Katakefalos promontory near its western limit. Because marble sits atop schist along most of the cape, stratigraphic offset at the fault provides a clear sense of displacement. The hanging wall has slipped such that the upper marble unit now lies adjacent to schist in the footwall (Fig. 4). The height of the contact suggests a throw of at least 20–30 m. A polished surface and grooves in the northeast-dipping breccia face suggest oblique slip of the hanging wall to the north (Fig. 3). Among the fault products are clasts of earlier breccia, visible in hand sample and thin section, indicative of at least one reactivation event.

Charasonas Headland

Two east-dipping, near-vertical subparallel breccia faces 10–15 m apart frame the fault zone at Charasonas, which extends for approximately 70 m on a NW–SE strike. A marble unit lies on the western side of the fault, and a schist unit on the eastern side. Between the two faces is a zone of variably hydrothermally altered matrix material and shattered host marble. Grooves and Riedel shear fractures in the marble footwall indicate oblique slip of the hanging wall to the north (Fig. 3).

PETROGRAPHY

Thin section analysis revealed microscopic stylolites in fine-milled calcareous fault material from Charasonas, providing evidence for syndeformational dissolution and diffusion. The stylolites occur as ragged, dark-fringed seams within the fine-ground matrix, and are commonly normal to calcite veins. In some cases, second-generation undeformed calcite has crystallized in gaps between stylolite contacts.

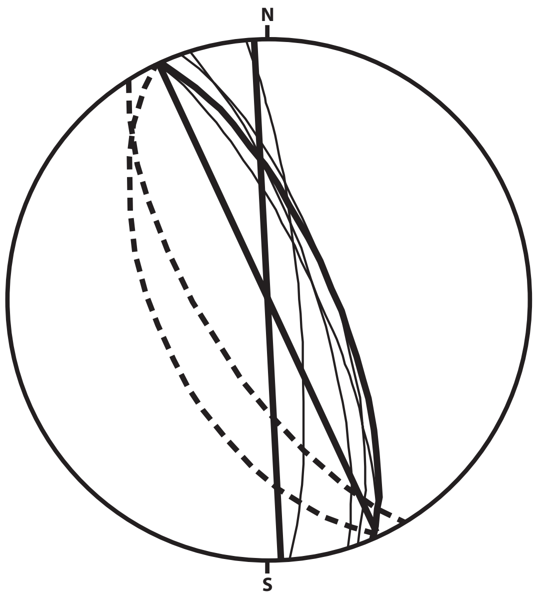

Figure 2: Equal-area stereonet of dominant fault planes at Diapori (dashed), Katakefalos (bold), and Charasonas (fine). Note that all planes are

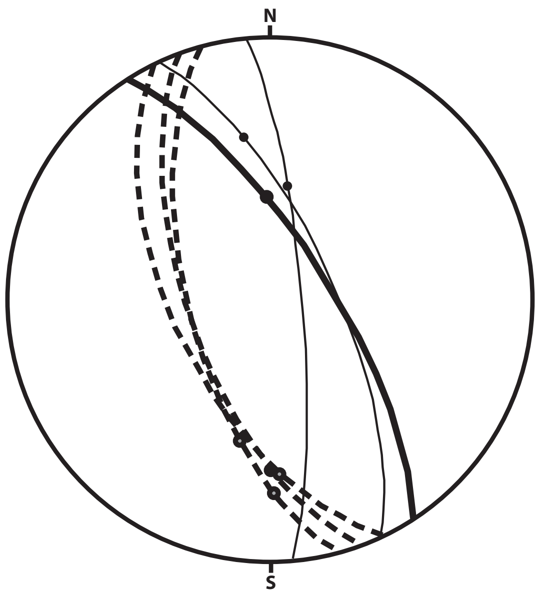

Figure 3: Equal-area stereonet of groove rakes (dots) and related fault planes at Diapori (dashed), Katakefalos (bold), and Charasonas (fine). Groove axes occur parallel to the direction of displacement. Grooves in west-dipping planes at Diapori show oblique slip to the south, while grooves in east-dipping planes at Katakefalos and Charasonas show oblique slip to the north.

Crystal plasticity records strain accumulation according to movement along lattice dislocations and mechanical twinning (Knipe, 1988). Inclusion-rich bands of deformation lamellae appear in fractured, crystalline quartz from Diapori and Charasonas. At high temperatures and in the presence of a reactive pore fluid, microfractures in quartz tend to suture and heal (Groshong, 1988). Open microfractures, therefore, suggest that the mineral is young and remained at relatively low temperatures. Calcite fragments from breccia samples show complex, contorted twinning that is more likely deformational than growth-related. Chains of fluid inclusions mark lattice planes within the calcite crystals.

ADDITONAL WORK

Field observations and petrographic descriptions can provide the context for fluid-inclusion analyses of fault matrix material from each of the three breccia zones. Quartz and calcite crystals in the breccia matrix contain fluid inclusions that can be analyzed with a fluid-inclusion stage to provide estimates of the depth and temperature of matrix formation. Most of the inclusions in the Syros samples contain fluid and a single gas bubble, indicating that the fluid was trapped at a higher temperature than occurs at surface conditions, causing the gas and fluid phases to separate during cooling. Comparisons among fluid inclusions in rebrecciated clasts, fresh fragments, matrix, and veins are possible using the fault rocks; inclusion comparisons between host rocks and fault material might indicate whether fluid movement was tightly confined to the fault, and whether fault fluids are chemically different from those in the surrounding rock units.

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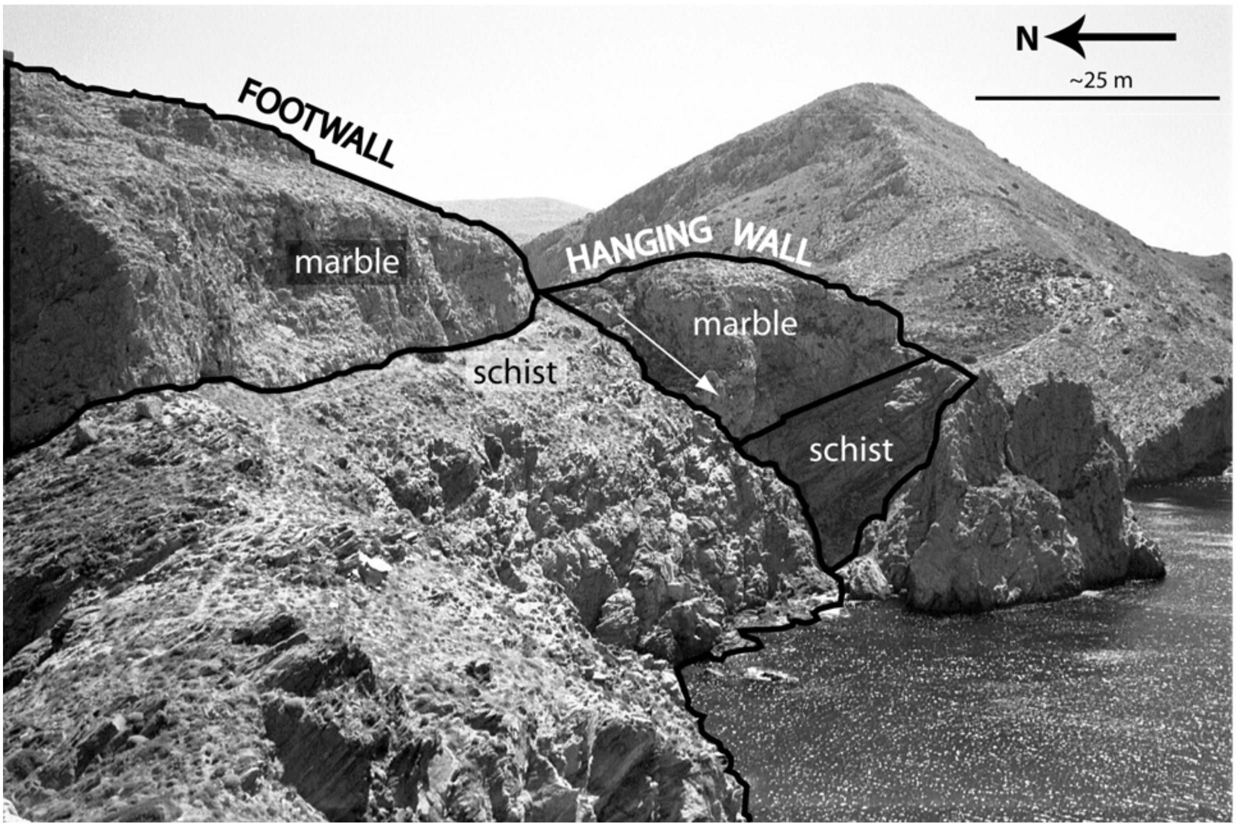

Figure 4: Fault zone at Katakefalos, view east. Footwall schist on the west side of the fault is juxtaposed against marble in the hanging wall to the east, a stratigraphic offset that provides a clear sense of displacement. The height of the contact suggests a throw of at least 20–30 m. The fault strikes NW–SE and dips 70–90º E. Grooves in a polished face suggest oblique slip to the NE.